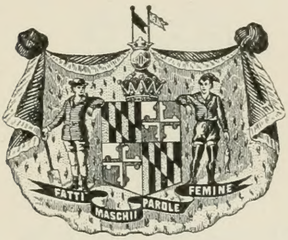
MARYLAND WEATHER SERVICE.

WM. BULLOCK CLARK, DIRECTOR.

THE CLIMATE AND WEATHER OF BALTIMORE.



PREPARED BY DIRECTION OF

WILLIS L. MOORE,

Chief of U. S. Weather Bureau.

BY

OLIVER LANARD FASSIG.

(Special Publication, Volume II.)

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BOARD OF CONTROL

The Maryland Weather Service is conducted under the joint auspices of the institutions above mentioned, the Central Office being located at the Johns Hopkins University. The meteorological work is under the immediate supervision of the Meteorologist who is detailed by the Chief of the U. S. Weather Bureau. Other lines of investigation are carried on in co-operation with various State and National organizations.

LETTER OF TRANSMITTAL

To His Excellency, EDWIN WARFIELD,

Governor of Maryland,

Sir:—I have the honor to present herewith the second volume of the new series of reports of the Maryland Weather Service. The first volume contained a general account of the physiography and meteorology of the State while the present volume is chiefly devoted to a special study of the climatic features of Baltimore and vicinity. I am,

Very respectfully,

WM. BULLOCK CLARK,

Director.

JOHNS HOPKINS UNIVERSITY,

December 1, 1907.

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PREFACE

The present volume is the second of a series of reports dealing with the climatic features of Maryland. The first volume was general in character and presented all that was then known regarding the physiography and meteorology of the State. The present and succeeding volumes will be devoted to more special studies within the province of climatological research.

The *Introduction* to the present volume, prepared by Wm. Bullock Clark, is devoted chiefly to an account of the operations of the Service together with the plans for future work. An account is given of the Swamp Lands of the State which are attracting wide attention. The writer refers to the Botanical Survey of the State, which has been made under the auspices of the State Weather Service, the results of which will be shortly printed in Volume III of the present series.

The *Report on the Climate and Weather of Baltimore and Vicinity,* discussed by Oliver L. Fassig, constitutes the chief portion of the volume and represents the result of many years of exhaustive study of the Baltimore region. All of the available records both public and private have been employed in this work and the result may be regarded as remarkably complete. It is doubtful if any district has received as thorough study as Dr. Fassig has given to that of Baltimore and vicinity. The report is divided into two parts. The first deals with the average and extreme values of the meteorological elements recorded in the city of Baltimore. The discussion is based upon careful observations extending over a period of nearly a century. The second part deals with types of weather experienced in Baltimore and vicinity—hence with the actual physical condition of the atmosphere at stated times, during the prevalence of storms, cold and warm waves, etc.

The Maryland Weather Service desires especially to extend its thanks to Professor Willis L. Moore, Chief of the U. S. Weather Bureau, who has generously aided the conduct of the investigations discussed in the present volume. Dr. Fassig has had access to the complete records of the U. S. Weather Bureau as well as to those of other official organizations.

Mr. E. W. Berry, of the State Geological Survey, has materially aided in editing the manuscripts for the volume.

INTRODUCTION

OPERATIONS OF THE SERVICE

BY

WM. BULLOCK CLARK

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The Maryland Weather Service has been engaged for many years in a study of the climatic features of Maryland. These investigations have resulted in the accumulation of a vast amount of information relating to the meteorology, the physiography, the agricultural soils, and the distribution of plant life. Much aid has been rendered the State Weather Service in this work by both the National and State bureaus.

Physiography and Climate of the State.

The results of the physiographic and meteorological studies of the entire state down to 1899 were presented in Volume I of this series of reports. These investigations were based on all the then existing observations and records, both official and private. The physiographic studies had been conducted largely under the auspices of the State Geological Survey, but as the results were so fundamental to an interpretation of the climatic features of the State, their publication in the very first volume of the new series of reports seems desirable.

The meteorological data relating to Maryland climate had been accumulated for over a century, but little attempt had been made hitherto to draw conclusions from them or to seek an explanation for the many variations that are found in the different sections of the state and in the

same regions at different seasons of the year. These studies may be regarded as preliminary to the more exhaustive investigations which have followed, as well as to those which still await completion.

Climate and Weather of Baltimore.

The investigations of the climate and weather of Baltimore and vicinity, discussed in the pages of the present volume, may be regarded as fully meeting the requirements of such a detailed study. The author has treated exhaustively the elements entering into the interpretation of the conditions found to prevail in the Baltimore region. It is probably the most complete study that has ever been given to the climate and weather of a single city and its environs, and will afford a most important storehouse of information for those who may be seeking for an accurate knowledge of the exact conditions that prevail in Baltimore and its immediate surroundings. The aid rendered by the Chief of the U. S. Weather Bureau has alone made it possible to secure the results here recorded.

Climate of the Counties.

Special reports on the climate of Allegany, Garrett, Cecil, Calvert, and St. Mary's counties have been prepared by the Maryland Weather Service and issued under the auspices of the Maryland Geological Survey in its series of county reports. It is the intention of the State Weather Service ultimately to bring together and publish these chapters when complete for all the counties in a single volume of the State Weather Service series. When brought out this report on the climate and weather of the Maryland counties will present for each political district of the State an exhaustive discussion of its special features that will be of great benefit to the inhabitants and to those seeking information regarding the special climatic conditions of any particular county. This study will take several years for its consummation, but with the co-operation so generously furnished by the Chief of the U. S. Weather Bureau it will be finally completed in a form that will be recognized as thoroughly authoritative.

The Meteorologist in charge of the State Weather Service, who has always been the representative of the U. S. Weather Bureau in Baltimore, has been hitherto designated by the Chief of the National Service to prepare these reports and has had access not only to the United States, but to the State records in this work. He has been able to employ the services of a trained body of men who would be otherwise entirely beyond the reach of the State for such an investigation.

Distribution of Plant Life in the State.

The distribution of animal and plant life, and more especially of the latter, is so intimately associated with the physiographic and climatic conditions that prevail that the Maryland Weather Service has undertaken a Botanical Survey of the State as a part of its climatic studies. For the past three years several trained botanists under the direction of Dr. Forrest Shreve have been engaged in the different sections of the state in making a detailed investigation of the botanical conditions. Not only has the distribution of plant life been found to be dependent on the climate and physiography of the state, but upon the agricultural soils which in turn find their ultimate interpretation in the underlying rocks from which they have been derived, thus bringing the work of the State Geological Survey and State Weather Service into close association.

The botanical survey is now completed and a report is at the present time being prepared, which will be issued as Volume III of the State Weather Service.

Survey of the Swamp Lands of the State.

A survey of the swamp lands of Maryland has been made in connection with the topographic survey of the state, in which the State Weather Service has participated with the State Geological Survey in its co-operation with the Topographic Branch of the U. S. Geological Survey. This survey has shown the following swamp areas.

AREA OF SWAMP LANDS IN THE VARIOUS COUNTIES COMPUTED FROM THE MARYLAND GEOLOGICAL SURVEY MAPS.

County.	Fresh.		Salt.		Total.	
	Sq. Mi.	Acres.	Sq. Mi.	Acres.	Sq. Mi.	Acres.
Baltimore	1.7	1,088	5.4	3,456	7.1	4,544
Anne Arundel	3.3	2,112	1.9	1,216	5.2	3,328
Prince George's ...	8.6	5,504	0.2	128	8.8	5,632
Charles	11.9	7,616	22.1	14,144	34.0	21,760
Calvert	3.2	2,048	1.2	768	4.4	2,816
St. Mary's	0.3	192	1.3	832	1.6	1,024
Harford	0.4	256	11.3	7,232	11.7	7,488
Cecil	0.2	128	6.5	4,160	6.7	4,288
Kent	0.4	256	7.9	5,056	8.3	5,312
Queen Anne's	9.7	6,208	4.5	2,880	14.2	9,088
Talbot	0.3	192	5.3	3,392	5.6	3,584
Caroline	9.7	6,208	2.6	1,664	12.3	7,872
Dorchester	78.3	50,112	123.2	78,848	201.5	128,960
Wicomico	17.1	10,944	22.1	14,144	39.2	25,088
Somerset	7.7	4,928	68.5	43,480	76.2	48,768
Worcester	33.0	21,120	35.4	22,656	68.4	43,776
Garrett	4.5	2,880	....	......	4.5	2,880
Other counties	4.0	2,460	....	......	4.5	2,560
Total	194.3	124,352	319.4	204,416	513.7	328,768

It will thus be seen that the State of Maryland has 328,768 acres of swamp lands, of which 124,352 acres are fresh-water swamps and 204,416 acres salt-water marshes. The eastern and southern counties of the state bordering the Chesapeake Bay and the Atlantic Ocean have 323,326 acres, of which 118,912 acres are fresh and 204,416 acres are salt. The central and western counties have 5440 acres, all of which are fresh.

The agricultural soil survey of Maryland, which is being carried on in co-operation with the U. S. Bureau of Soils, shows a considerably larger acreage of swamp lands in those counties surveyed than the estimates above given, but in the soil survey the small tracts on individual farms were computed, while the topographic maps show only the larger areas, which would alone be considered in any plan of government reclamation. Counting these small tracts the total area would probably reach 500,000 acres.

A fuller study of these swamp lands is now in progress and as their present condition is intimately connected with the climatic conditions of

the State their study, in part at least, falls within the province of the State Weather Service.

OTHER LINES OF WORK.

The far reaching influence of climate on the economic and social development of the state suggests other lines of investigation that require the attention of the State Weather Service.

The character of the agricultural soils, although fundamentally determined by the underlying rocks, is also to no small degree dependent on the physiography and climatic features of the State. These factors must be considered in any comprehensive study of the agricultural soils.

The health of any community is also to no inconsiderable extent dependent on the climate, and this is recognized in the field of investigation known as medical climatology. In Volume I the present writer said in discussing this subject in his "Plan of Operation of the Service" that "the healthfulness of Maryland as a place of residence is a question of no small importance to those who may be considering the advisability of seeking homes in our midst, and actual facts should be presented in such a manner as to command their attention. The various sections of the state, their marked differences in temperature and rainfall, may be shown to be adapted to the physical requirements of different people, and it is highly important that these facts should be made known.

"It is also probable, as the meteorological records over considerable periods are carefully studied, that some districts will be found highly beneficial to people suffering from certain ailments. It is the purpose of the Maryland Weather Service to have some expert upon medical climatology carefully study its records and prepare a report upon this subject, and already arrangements to this end have been perfected."

The general and special studies earlier enumerated naturally afford the basis for a consideration of the crop conditions of the State and this subject should be taken up in a comprehensive way as the data collected become adequate to the discussion of so great a subject. The agricultural products of the State far surpass those in every other line, and the State Weather Service should give whatever assistance it can in the study of the important problems involved.

It is also a well recognized fact that the character and distribution of forest growth is in no small degree determined by the climatological features which have already been described. Since forestry studies were organized by the State Geological Survey a few years ago a State Board of Forestry has been organized and the investigation of our forests is now well under way. The State Weather Service can aid in various ways in this work.

The climate in its various relations touches human life in so many points that the investigations already undertaken and proposed will prove not only of great interest, but of greater value to the people of the state. Results of real worth can rarely be obtained quickly, but the investigations now being conducted by the State Weather Service are of a fundamental character, and when completed will cover as fully as possible the field of climatology in its various relations to the economic interests of the State.

REPORT ON THE

CLIMATE AND WEATHER

OF

BALTIMORE AND VICINITY

(Based on the Observations of the U. S. Weather Bureau; Supplemented by Observations of the Maryland State Weather Service, and the U. S. Army Medical Department.)

PREPARED BY DIRECTION OF

WILLIS L. MOORE

CHIEF OF U. S. WEATHER BUREAU

BY

OLIVER LANARD FASSIG

THE CLIMATE OF BALTIMORE

INTRODUCTION

For more than thirty years the United States Weather Bureau has maintained a station of the first order in Baltimore City. During all these years the weather conditions have been carefully and accurately noted and recorded at several stated hours of the day by trained observers. In 1893 the instrumental equipment of the station was greatly increased and the value of the records enhanced by the acquisition of additional self-recording instruments by means of which a continuous record has been obtained of all the principal elements of the weather. The records of the Baltimore station now show the local state of the atmosphere during every hour of the day and night since 1893, barring an occasional brief break in the record due to accidental causes. The factors thus continuously noted are the temperature of the atmosphere, the pressure, rainfall, sunshine, wind velocity, wind direction and, since 1902, the humidity. This mass of exceedingly valuable raw material for the study of problems in local climatology, supplemented by an almost unbroken series of local observations made since 1817 under the auspices of the United States Army Medical Department and the Smithsonian Institution, has never before been subjected, as a whole, to a critical analysis and reduction. It is evident that such observations, secured at enormous expense of time and money, should yield benefits beyond their immediate uses at the time of recording, however valuable these may be.

The weather conditions at Baltimore are typical of conditions within a wide area. Allowing for small differences in amplitude of variation due to local surface conditions, an analysis of the Baltimore observations may with safety be applied to much of that portion of the Middle Atlantic States lying east of the Appalachian Mountains. This area lies about midway between the rigorous north and the mild south, the equable ocean region and the region of great variability in the interior of the continent.

Rainfall is abundant and quite uniformly distributed throughout the year. Storms of destructive violence are of rare occurrence; tornadoes are almost unknown. The season of safe plant growth is long, and sunshine is abundant.

In the following report the analysis of the observations is divided into two distinct parts. The first part deals with the *average conditions* of the atmosphere, derived from many years of statistical data relating to temperature, pressure, humidity, rainfall, clouds and sunshine, winds, etc., and to departures from their normal values. In brief, it deals with the *climate* of the region about Baltimore. The second part is devoted to the *weather,* or *actual conditions* of the atmosphere at any given time as regards temperature, humidity, rainfall, clouds, wind—the sum total of the atmospheric conditions. Hence *weather* is a *passing phase* of *climate.* Attention will be directed largely to storms, cold waves, hot waves, etc., as well as to the gentler phases of the atmosphere which constitute the daily routine of weather. This division into climate and weather is necessarily more or less arbitrary, and the lines of demarcation employed by different writers will seldom be found in exactly the same places, nor will the strict definition be consistently adhered to in the practical treatment of the subjects by the same writer. But the division is, in the main, logical and a convenient one for all practical purposes.

Without entering unduly into details regarding the plan of Part I, attention may be directed to the order of discussion of the climatic factors. As far as possible each element has been considered with reference, (a) to its diurnal period, (b) its annual period, (c) its variability, or non-periodic aspects of short and long duration. Tables and diagrams have been freely employed, the statistical tables permitting of greater accuracy of statement, the graphic method affording a readier means of presenting at a glance the salient features of the variability of the climatic elements from hour to hour, or from season to season.

The Geographical Horizon of Baltimore.

The State of Maryland is situated within three distinct physiographic provinces. The low, flat Coastal Plain, averaging about 60 feet above mean tide and cut up by tidal estuaries, extends from the Atlantic seaboard westward to a line joining Philadelphia, Baltimore and Wash-

ington, where it is separated sharply from the Piedmont Plateau, or middle province. The Piedmont Plateau is an undulating area with elevations rising to 700 feet or 800 feet, and extending westward to the mountainous and high plateau region of the Appalachian Province. The mountains of this latter province form a system of parallel ranges extending from northeast to southwest across the state, rising to heights of 3000 feet. The city of Baltimore is partly on the Piedmont Plateau and partly on the Coastal Plain. The country to the north and west is gently undulating; to the east and south it is level and but a few feet above the adjacent estuaries of Chesapeake Bay.

ATMOSPHERIC PRESSURE.

As a direct climatic factor the pressure of the atmosphere, and variations in this pressure, are of comparatively minor importance. The effect of changes in the height of the barometer upon the human system does not begin to be recognized until the rise or fall is very marked. A diminished pressure causes in most persons a feeling of lassitude with increased difficulty of breathing. But this physiological effect is not experienced, excepting by extremely sensitive persons, until the barometer shows a fall of three or four inches, equivalent to an ascent of three or four thousand feet above sea-level. The extreme variations of pressure at any one place do not often exceed an inch within the period of a few days. At Baltimore the extreme range has been but slightly over two inches in the past thirty-three years. The change in the pressure experienced during the passage of the severest type of cyclonic disturbance is less than the permanent difference in pressure between the eastern and the higher western portions of the State of Maryland; and hence less than is experienced by travelers daily in passing from Baltimore to Pittsburg, over the Alleghany Mountains. As an indirect factor, however, in the climates of the world, and as a direct agency in causing movements of the atmosphere, the pressure changes are of the highest importance and take rank with those of temperature and rainfall.

In another part of this report, the more general relations of pressure will be discussed in connection with the consideration of storm movements. The following pages are devoted mostly to the local conditions

and variations of pressure at Baltimore, based upon observations made since 1871 under the auspices of the United States Weather Bureau. Observations were begun in Baltimore on January 1, 1871, and have been maintained in an unbroken series to the present time. Standard

TABLE I.—MEAN HOURLY BAROMETRIC PRESSURE.

[In inches and thousandths.]

29.000 inches. Local time is 6 minutes slow.

75th mer. time.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1 A. M.	.939	.885	.892	.874	.821	.840	.835	.850	.923	.959	.959	.966	0.895
2	.938	.883	.888	.869	.817	.836	.831	.847	.920	.955	.959	.967	0.892
3	.940	.880	.883	.867	.816	.835	.830	.846	.920	.952	.958	.967	0.891
4	.936	.879	.883	.868	.818	.840	.835	.848	.922	.954	.959	.964	0.892
5	.937	.881	.891	.875	.826	.849	.844	.855	.929	.960	.964	.963	0.898
6	.947	.886	.900	.886	.837	.858	.852	.864	.938	.967	.970	.968	0.906
7	.953	.894	.910	.897	.845	.866	.861	.874	.948	.979	.981	.978	0.916
8	.965	.906	.916	.901	.851	.871	.866	.880	.954	.993	.991	.990	0.924
9	.978	.912	.920	.901	.852	.871	.867	.883	.959	.994	.995	.996	0.927
10	.981	.911	.917	.900	.850	.868	.865	.883	.958	.992	.993	1.003	0.927
11	.974	.906	.908	.892	.843	.863	.859	.878	.949	.985	.981	.990	0.919
Noon	.952	.891	.896	.879	.832	.854	.850	.868	.938	.969	.963	.971	0.905
1	.931	.869	.877	.866	.819	.841	.838	.856	.922	.951	.944	.950	0.889
2	.920	.855	.862	.852	.806	.830	.825	.842	.908	.937	.934	.940	0.876
3	.918	.851	.854	.840	.794	.819	.813	.831	.897	.931	.932	.939	0.868
4	.921	.851	.849	.835	.787	.810	.805	.825	.891	.929	.936	.944	0.865
5	.926	.857	.853	.835	.784	.807	.802	.823	.891	.932	.941	.950	0.867
6	.932	.866	.860	.838	.786	.810	.804	.823	.894	.939	.950	.956	0.872
7	.940	.875	.871	.848	.795	.817	.810	.831	.903	.946	.957	.966	0.880
8	.943	.878	.880	.863	.806	.826	.819	.841	.914	.954	.964	.971	0.888
9	.945	.883	.888	.872	.817	.836	.830	.851	.923	.957	.965	.972	0.895
10	.945	.885	.892	.877	.820	.842	.835	.855	.926	.961	.966	.973	0.898
11	.943	.883	.892	.880	.822	.844	.836	.857	.928	.960	.965	.973	0.899
Midnight	.939	.881	.893	.881	.822	.843	.835	.857	.926	.958	.963	.970	0.897
Average	.943	.881	.886	.871	.820	.841	.835	.853	.924	.959	.962	.968	0.895

Table I contains the average hourly values of the *station* pressure at Baltimore for the period of ten years from 1893 to the close of 1902. The values are derived from the continuous record of a Richard barograph, corrected to agree with personal observations of a mercurial barometer made daily at 8 a. m. and 8 p. m. Each mean hourly value for the year is based on over 3600 observations; hence these values may be regarded as very close approximations to normal averages for each hour of the day for the year. The station elevation has been 123 feet above mean tide since August 1, 1896. The average hourly pressures are also shown graphically in Figs. 1 and 2.

mercurial barometers were read at stated hours from two to five times daily. Since 1893 a self-recording barograph has furnished a continuous record of the pressure conditions and changes, affording excellent material for an analysis of the diurnal fluctuations of the barometer. The rich and abundant material accumulated by the Weather Bureau during the past thirty-three years has been reduced and discussed with

a view to disclosing the nature of the diurnal and annual periodic changes of pressure, as well as the irregular and secular changes.

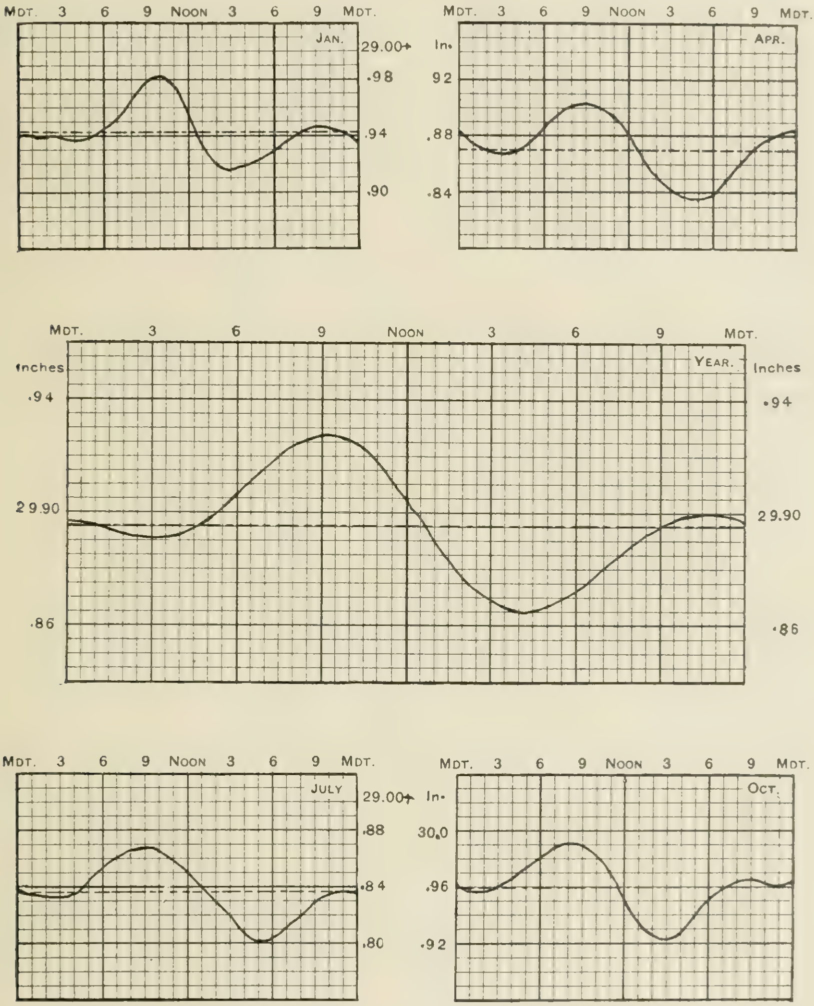


FIG. 1.—Hourly Variations of the Barometer.

Fig. 1. The *average* height of the barometer at each hour of the day for the ten years from 1892 to 1903 is shown in the above diagrams for the months of January, April, July, Oct., and for the entire year. The height of the column of mercury which the pressure of the atmosphere sustained is expressed in inches and hundredths of an inch. See also Fig. 2, and Table I.

The Diurnal Variations of the Barometer.

Within the tropics, where cyclonic storms are of infrequent occurrence, the diurnal variation of the barometer is the most marked feature of the barometric curve. So regular in form and distinct in outline are these changes that it is possible by inspection of the curve to tell approximately the time of day. The amplitude of oscillation near the equator is about one-eighth of an inch. This amplitude decreases with distance from the equator but is still recognizable in the latitude of 70 degrees. Along the parallel of Baltimore the amplitude is quite marked in a curve representing average hourly changes for the period of a month or more, but is detected only by the experienced eye in the daily curve, owing to the relatively large irregular changes due to the passage of the cyclonic storms of the middle latitudes. At times, especially in the summer months when tropical conditions prevail for a considerable period in our latitudes, the diurnal variation is very distinct for days at a time. (See the curve for August 7-13, 1900, on Plate II.)

THE NORMAL DIURNAL VARIATION AT BALTIMORE.

The mean hourly values of barometric pressure for Baltimore are presented in Table I for each month and for the year. The results for each season and for the entire year are also shown graphically in Fig. 1 on page 33 and Fig. 2 on page 36. In Table II the same values are expressed in terms of departures from the average value for the entire day. These tables and diagrams reveal for Baltimore the characteristic double barometric curve so well known to the meteorologist from the results of analyses of observations in all parts of the world, with perhaps minor peculiarities due to local conditions. The fluctuations are well marked in all months of the year, the amplitude varying from 0.060 inch in August to 0.071 inch in March. In Fig. 2 the distribution of pressure is presented by a method not frequently employed but one which shows clearly and in compact form the successive changes from hour to hour throughout the year. Upon a system of coordinates representing the hours of the day and the months of the year, the curved lines of equal pressure are projected in such manner as to enable one to find the exact pressure at any hour of any month. These curved lines are sometimes called "isopleths." For example, to find the average pressure at noon

in April, you run down the vertical line marked noon, until the horizontal line marked April is intercepted, and find the isopleth of 29.875. This method enables us also to see at a glance the chief characteristics of the seasonal distribution, further emphasized by differences in shading, the lighter shades indicating the lower pressures of the warm months and the darker shades the higher pressures of the colder months.

TABLE II.—HOURLY DEPARTURES FROM MEAN DAILY PRESSURE.

[In thousandths of an inch.]

Local time is 6 minutes slow.

75th mer. time.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1 A. M.	—.004	.004	.006	.003	.001	—.001	.000	—.003	—.001	.000	—.003	—.002	.000
2	—.005	.002	.002	—.002	—.003	—.005	—.004	—.006	—.004	—.004	—.003	—.001	—.003
3	—.003	—.001	—.003	—.004	—.004	—.006	—.005	—.007	—.004	—.007	—.004	—.001	—.004
4	—.007	—.002	—.003	—.003	—.002	—.001	.000	—.005	—.002	—.005	—.003	—.004	—.003
5	—.006	.000	.005	.004	.006	.008	.009	.002	.005	.001	.002	—.005	.003
6	.004	.005	.014	.015	.017	.017	.017	.011	.014	.008	.008	.000	.011
7	.010	.013	.024	.026	.025	.025	.026	.021	.024	.020	.019	.010	.021
8	.022	.025	.030	.030	.031	.030	.031	.027	.030	.034	.029	.022	.029
9	.035	.031	.034	.030	.032	.030	.032	.030	.035	.035	.033	.028	.032
10	.038	.030	.031	.029	.030	.027	.030	.030	.034	.033	.031	.035	.032
11	.031	.025	.022	.021	.023	.022	.024	.025	.025	.026	.019	.022	.024
Noon	.009	.010	.010	.008	.012	.013	.015	.015	.014	.010	.001	.003	.010
1	—.012	—.012	—.009	—.005	—.001	.000	.003	.003	—.002	—.008	—.018	—.018	—.006
2	—.023	—.026	—.024	—.019	—.014	—.011	—.010	—.011	—.016	—.022	—.028	—.028	—.019
3	—.025	—.030	—.032	—.031	—.026	—.022	—.022	—.022	—.027	—.028	—.030	—.029	—.027
4	—.022	—.030	—.037	—.036	—.033	—.031	—.030	— 028	—.033	—.030	—.026	—.024	—.030
5	—.017	—.024	—.033	—.036	—.036	—.034	—.033	— 030	—.033	—.027	—.021	—.018	—.028
6	—.011	—.015	—.026	—.033	—.034	—.031	—.031	—.030	—.030	—.020	—.012	—.012	—.023
7	—.003	—.006	—.015	—.023	—.025	—.024	—.025	—.022	—.021	—.013	—.005	—.002	—.015
8	.000	—.003	—.006	—.008	—.014	—.015	—.016	—.012	—.010	—.005	.002	.003	—.007
9	.002	.002	.002	.001	—.003	—.005	—.005	—.002	—.001	—.002	.003	.004	.000
10	.002	.004	.006	.006	.000	.001	.000	.002	.002	.002	.004	.005	.003
11	.000	.002	.006	.009	.002	.003	.001	.004	.004	.001	.003	.005	.004
Midnight	—.004	.000	.007	.010	.002	.002	.000	.004	.002	—.001	.001	.002	.002

Table II contains the average hourly departures from the normal monthly *status* pressures recorded in Table I, the values being expressed in thousandths of an inch of pressure. Figures preceded by the minus sign represent values below the normal for the day; those without sign represent values above the normal. For example, examining the column headed "year" we observe that: the atmospheric pressure is at or below the average for the day from 1 a. m. to 4 a. m., above the average from 5 a. m. to noon, falls below the mean again at 1 p. m., remaining below until 8 p. m., then again exceeding the mean to midnight; that the average time of the primary maximum for the day occurs between 9 a. m. and 10 a. m., and the primary minimum at 4 p. m.; that a secondary maximum occurs at 11 p. m., and a secondary minimum occurs at 3 a. m. The maximum and minimum phases vary from month to month as shown in Table III and in Fig 3.

PHASES OF THE DIURNAL OSCILLATION.

The four principal phases are distinctly revealed in all of the normal curves (see Figs. 1, 2 and 4). The primary, or morning, maximum

occurs about 9.15 a. m., local time, on the average during the year. The time varies with the season. During the winter months the crest of the maximum wave occurs about half an hour later and during the summer months half an hour earlier, making a difference of about an hour between the earliest and latest *average* appearance. The most variable in time of appearance is the primary, or afternoon, minimum. From January, when this phase occurs about 3 p. m., there is a steady retardation in the time of occurrence of the minimum to about 5 p. m. in May, where it remains until August, when the time again moves forward to the winter minimum at 3 p. m. The average occurrence of the

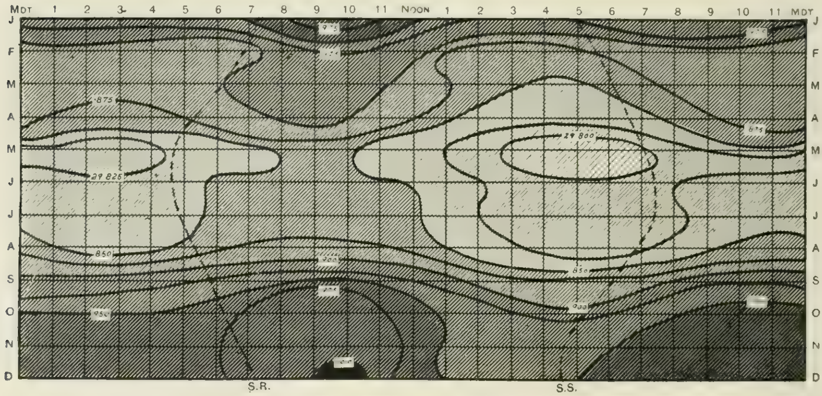


FIG. 2.—Isopleths of Hourly Pressure.

Fig. 2 shows the average distribution of atmospheric pressure throughout the day and year, based on observations of ten years of hourly readings of the barograph. The upper marginal figures indicate the hour of the day, the marginal letters indicate the months of the year. The line enclosing the area of lightest shading defines the time of day and month when the barometer is normally lowest; increase in the intensity of shaded areas shows an increase in the height of the barometer. The diagram shows that the barometer is lowest at about 5 p. m. in the month of May; that it is highest at 10 a. m. in the month of December. The curved lines show the hours of the day and the months of the year when the barometer readings are, on the average, equal; these lines are called chrono-isobars, or isopleths of pressure. The dotted lines marked S.R. and S.S. show the time of sunrise and sunset. See also Table I.

minimum for the year is about 4.15 p. m., local time. The secondary, or night, maximum occurs about 11 p. m., the time of occurrence being fairly constant but varying from 10 p. m. in December to 11.30 p. m. in the summer months. The secondary, or night, minimum occurs quite uniformly at 3 a. m. from May to December, with extreme limits

of 3.30 a. m. in January and February and 2.30 a. m. in April. The most marked feature of the variations in time of occurrence of the different phases is the gradual increase in the time interval between the

TABLE III.—PRESSURE PHASES.

(75th meridian time.—Local time is 6 minutes slow.)

	Morning maximum.				Afternoon minimum.						Night maximum.							Night minimum.							
	a. m.			Average a. m.	p. m.					Average p. m.	p. m.					a. m.	Average p. m.	Mid-n't.	a. m.						Average a. m.
	8	9	10		2	3	4	5	6		8	9	10	11	12	1		12	1	2	3	4	5	6	
January	1	6	6	9:30	..	7	4	1	..	3:00	..	2	2	1	1	4	11:00	..	2	1	2	6	..	..	3:30
February	1	6	6	9:30	..	7	4	1	..	3:00	..	3	3	2	1	1	10:30	..	1	1	2	6	..	1	3:30
March	1	9	1	9:00	..	1	7	2	..	4:00	..	1	3	1	3	2	11.00	..	..	..	7	4	1	..	3:00
April	2	9	3	9:00	..	1	6	4	..	4:30	..	..	1	4	4	2	11:30	..	..	5	2	3	..	..	2:30
May	6	5	..	8:30	..	..	1	8	2	5:00	..	..	1	4	3	2	11:30	..	..	5	6	2	..	..	3:00
June	6	6	..	8:30	..	..	1	9	..	5:00	..	..	3	6	3	1	11:00	..	1	4	7	..	..	..	3:00
July	5	6	2	9:00	..	..	2	4	3	5:00	..	..	..	4	3	3	11:30	..	..	3	7	..	..	..	3:00
August	..	4	5	9:30	..	..	..	6	5	5:30	..	..	2	6	5	..	11:30	..	..	2	6	2	..	..	3:00
September	..	7	3	9:00	..	1	3	4	1	4:30	..	..	2	8	1	..	11:00	..	1	4	7	1	..	..	3:00
October	1	6	4	9:00	..	2	7	1	..	4:00	..	..	4	4	1	2	11:00	..	..	1	6	3	..	..	3:00
November	2	7	2	9:00	2	7	..	..	..	3:00	3	..	4	1	1	..	10:00	1	3	2	5	2	..	..	3:00
December	..	..	8	10:00	3	7	..	..	..	3:00	1	2	4	2	1	..	10:00	..	3	1	1	..	4	..	3:00
Sums	25	71	40	....	5	33	35	40	11	....	4	8	29	43	27	17	....	1	11	29	58	29	5	1	....
Annual average	2	10	3	9:08	..	4	4	6	1	4:08	..	1	5	6	4	..	10:55	..	..	1	9	3	1		3:05

Table III shows the average hour of occurrence of the daily maximum and minimum *station* pressure for each month and for the year during a period of ten years, and also the extent to which the times of occurrence of these phases have varied from the average time. For example, examining the afternoon minimum phase, the most variable of all, we find that in 10 years it occurred in January 7 times at 3 p. m., 4 times at 4 p. m., and once at 5 p. m.; and that the average time of occurrence for the year is about 3 p. m.; that in August it occurred at 5 p. m. 6 times and at 6 p. m. 5 times; and as an average time we have about 5.30 p. m., etc. The average values are also shown graphically in Fig. 3.

primary maximum and primary minimum with the approach of summer, from five hours and a half in the winter months to eight hours and a half in May and June. This increasing interval is due mostly to variations in the time of occurrence of the primary minimum. These phases are shown in detail in the following table and in Fig. 3.

INTERVALS BETWEEN PRINCIPAL PHASES OF PRESSURE.

(Expressed in Hours and Minutes.)

Intervals between.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
A. Primary max. and min.	5:30	5:30	7:00	7:30	8:30	8:30	8:00	8:00	7:30	7:00	6:00	5:00	7:00
B. Secondary max. and min.	4:30	5:00	4:00	3:00	3:30	4:00	3:30	3:30	4:00	4:00	5:00	5:00	4:05

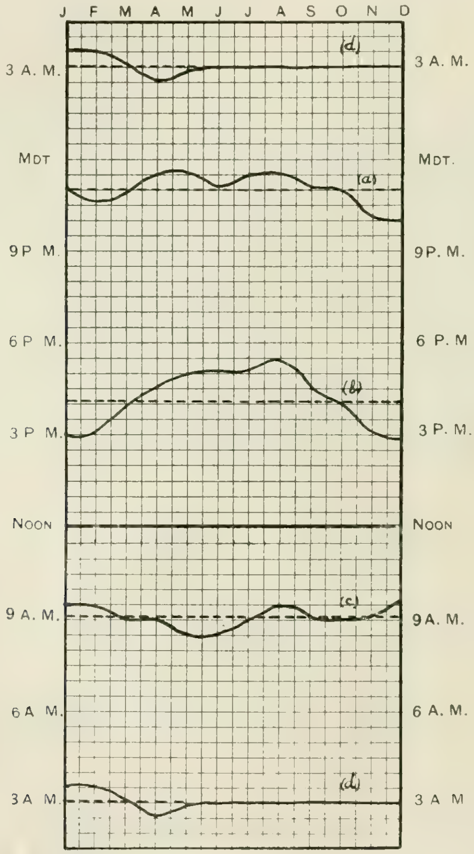


FIG. 3.—Principal Phases of Diurnal Oscillation of Pressure.

Fig. 3 indicates the time of occurrence of the maximum and minimum points reached by the barometer in the diurnal oscillation. The upper marginal letters represent the months of the year; the figures indicate the hours of the day. The curved lines represent respectively (*a*) the time of occurrence of the secondary maximum; (*b*) the primary minimum; (*c*) the primary maximum; (*d*) the secondary minimum. See also Table III.

AMPLITUDE OF OSCILLATION.

(In Thousandths of an Inch.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
A. Diurnal Amplitude.	63	61	71	66	68	64	65	60	68	65	63	64	62
B. Nocturnal Amplitude.	9	6	10	14	6	9	6	11	8	9	8	10	7

TABLE IV.—HOURLY VARIATIONS OF PRESSURE ON CLEAR AND ON CLOUDY DAYS.

(Expressed in thousandths of an inch as departures from the daily average.)

75th Meridian Time.	Clear days in		Total (90 days) Departure.	Cloudy days in		Total (90 days) Departure.
	Jan. and Feb. (60 days) Departure.	July (30 days) Departure.		Winter (60 days) Departure.	Summer (30 days) Departure.	
Midnight	—.052	—.006	—.028	—.003	—.001	.000
1	—.037	—.006	—.022	+.010	—.004	+.003
2	—.029	—.007	—.018	+.013	—.011	+.001
3	—.021	—.008	—.014	+.012	—.014	—.001
4	—.018	—.002	—.010	+.006	—.011	—.002
5	—.005	+.009	+.002	+.006	—.004	+.001
6	+.004	+.018	+.011	+.008	+.011	+.010
7	+.022	+.028	+.025	+.015	+.023	+.019
8	+.041	+.034	+.038	+.024	+.029	+.026
9	+.056	+.034	+.045	+.032	+.034	+.033
10	+.063	+.032	+.048	+.034	+.030	+.032
11	+.058	+.028	+.043	+.024	+.027	+.026
Noon	+.040	+.023	+.032	+.004	+.020	+.012
1	+.019	+.009	+.014	—.016	+.005	—.006
2	+.003	—.004	.000	—.025	—.003	—.014
3	—.008	—.017	—.012	—.027	—.011	—.019
4	—.013	—.026	—.020	—.027	—.017	—.022
5	—.014	—.038	—.024	—.023	—.020	—.022
6	—.014	—.035	—.024	—.025	—.017	—.021
7	—.012	—.031	—.022	—.011	—.013	—.012
8	—.015	—.025	—.020	—.006	—.004	—.005
9	—.019	—.016	—.018	—.003	+.001	—.001
10	—.026	—.013	—.020	—.003	+.003	.000
11	—.036	—.008	—.022	+.003	+.001	+.002
Midnight	—.051	—.006	—.028	+.001	+.001	.000

Table IV shows the amount of the diurnal variation of pressure on clear days as compared with cloudy days in order to detect any difference due to cloudiness. For this purpose 60 clear days in January and February and 30 clear days in July were chosen, to be compared with 60 cloudy days in January and February and 30 cloudy days in July. The effect of irregular variations of the barometer due to the passage of storms was first eliminated from the actual means. The results are also graphically shown in Fig. 4.

In individual months the time of occurrence of these phases varies considerably from the average times for the entire ten years, as may be seen in Table III, which shows the frequency of occurrence of the different phases for each month for the ten-year period.

DIURNAL VARIATIONS OF PRESSURE ON CLEAR AND CLOUDY DAYS.

In Tables I and II and Figs. 1 and 2 the average distribution of pressure is shown for all conditions of the weather during a period of ten years. In order to determine the effect, if any, of cloudiness upon the oscillation of pressure, selection was made of 60 *clear* days in January and February and 30 in July to be compared with a like number of

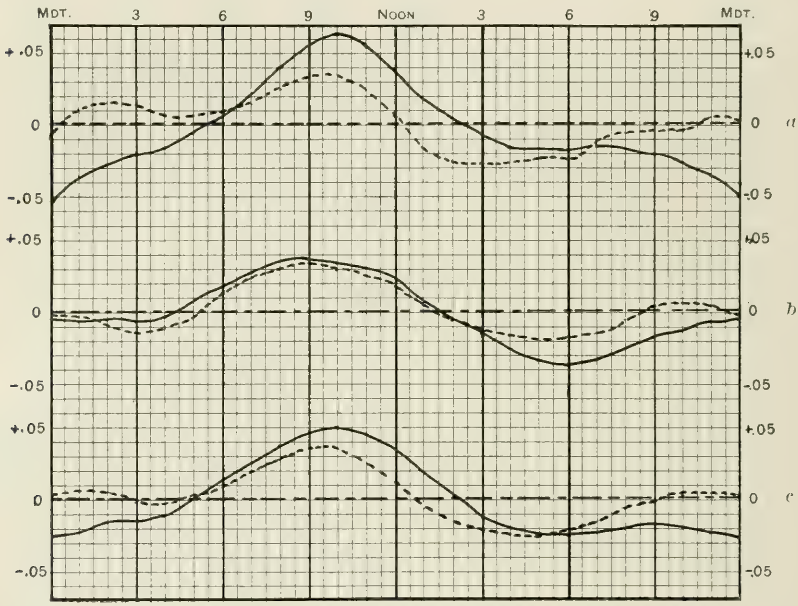


FIG. 4.—Diurnal Variations of Pressure on Clear and on Cloudy Days.

——— Clear. - - - - - Cloudy.

Fig. 4 shows the hourly changes of the barometer on selected days approximately similar in all respects excepting as to the amount of cloudiness. The continuous lines show the movements of the barometer on clear days and the dotted lines on cloudy days, for (*a*) winter months, (*b*) summer months, and (*c*) for the year. The hourly heights of the barometer are expressed in hundredths of an inch, as departures from the average height for the entire day. See also Table IV.

cloudy days in the same months, as far as possible. The computed variations are shown in tabular form in Table IV, and graphically in Fig. 4, on page 40, after first eliminating the effect of irregular fluctuations of the barometer due to passing cyclonic disturbances. The primary maximum and minimum phases differ but little from those of

the normal curve, although the amplitude on clear days is somewhat exaggerated, especially so during the winter months. The curves for the normal and for the cloudy days coincide very closely for the summer months and for the year, but diverge in the early morning hours of the winter months. The most striking feature of the curve for totally clear days is the wide divergence from the normal curve in winter during the night and early morning hours.

THE DIURNAL BAROMETRIC WAVE.

The diurnal variations of the barometer described in the preceding paragraphs are not simply of local occurrence but are part of a general phenomenon extending over the greater portion of the earth's surface. The maximum and minimum phases pointed out occur in all localities at approximately the same hours of local time. As stated above, this pressure wave, as it may be called, has its greatest development in or near the equatorial belt, and diminishes in amplitude with distance north and south of the equator. It has some resemblance to a double atmospheric wave passing completely round the earth from *east* to *west* every twenty-four hours, having a velocity at the equator of about one thousand miles per hour. By plotting upon a map of the world the departures from the normal daily pressure for successive hours of the day at a large number of stations uniformly distributed over the northern and southern hemispheres, and joining such stations as have equal departures of pressure for the same hour, we have presented to us four systems of pressure-distribution, consisting of two areas of low pressure and two areas of high pressure. These systems completely encircle the globe and closely resemble in form the cyclonic and anticyclonic systems of the middle latitudes, but differ from them, among other things, in covering an area vastly greater, and in moving in the opposite direction. The diurnal fluctuations of the barometer are the local evidence of this vast double atmospheric wave passing round the globe daily. The westward propagation of these waves near the equator is represented in Fig. 5 on page 42; the curve shows the time of occurrence of the different phases of the double wave, its amplitude, and the direction of propagation along the path of greatest development. The character of these waves is further indicated in the diagrams of Plate I. in which the succes-

sive areas of high and low pressure are exhibited at intervals of two hours in passing from east to west across the North and South American continents.[1]

This double atmospheric wave, or tide, is so intimately associated with the apparent diurnal movements of the sun that the conclusion is almost irresistible that the pressure changes are due primarily to changes of temperature. This relationship has not yet been satisfactorily demonstrated to be that of direct cause and effect, but there seems to be a general consensus of opinion that the primary maximum and the primary minimum phases of pressure are direct effects of the sun's heat. The

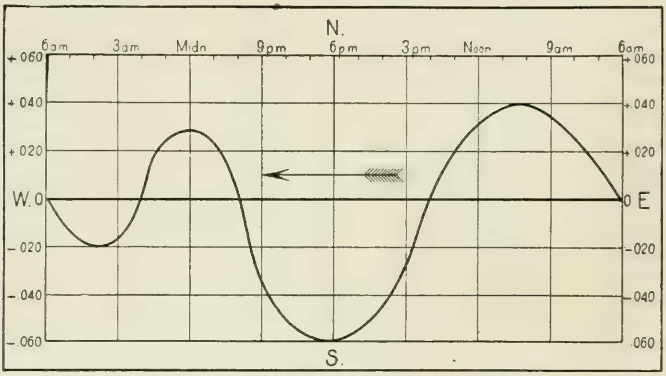
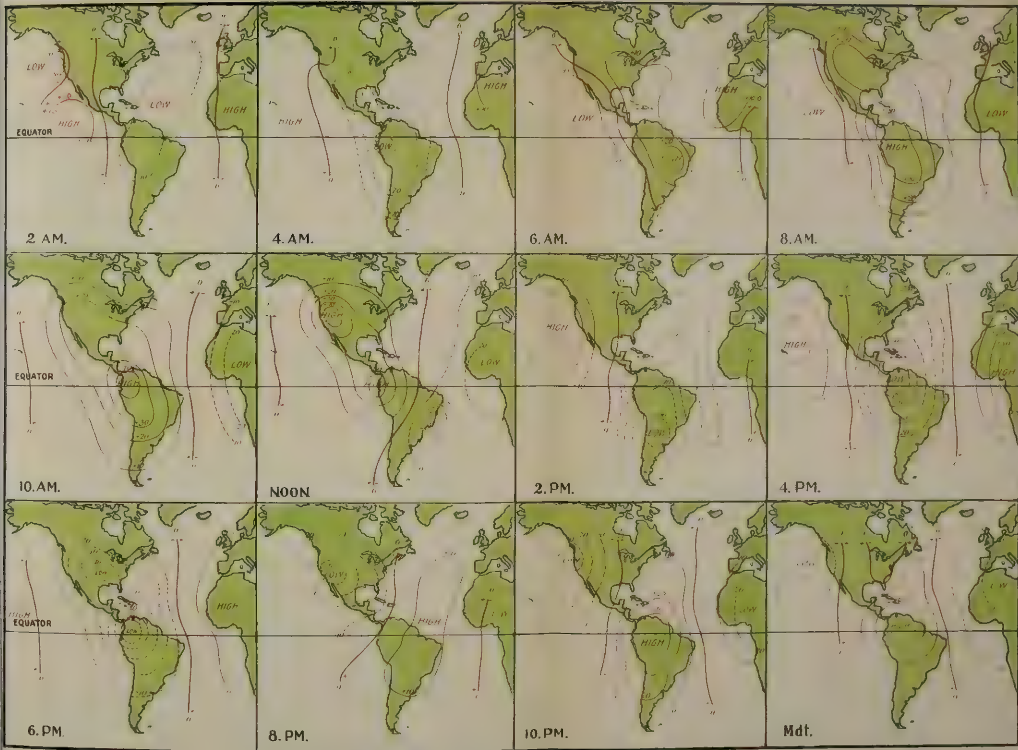


FIG. 5.—The Diurnal Barometric Wave.

Fig. 5 shows the direction of movement of the diurnal barometric wave, from east to west around the globe; also the local time at which the crests and the hollows of the wave pass over any locality along the path of the greatest development of the wave, near the equator. The extent of the diurnal rise and fall of the barometer is shown by the figures to the right and left of the diagram, which express the departures above and below the normal height for the day, in thousandths of an inch of mercury. See also Plate I.

theory advanced many years ago to account for the chief maximum and minimum phases seems plausible. At the time of day, between 9 a. m. and 10 a. m., when the atmosphere is being warmed most rapidly and the tendency of the air to rise in consequence is greatest, the upper and colder layers impede this upward movment. resulting in a temporarily increased tension at the surface of the earth. When this tension is relieved the barometer begins to fall. reaching its lowest point about the

[1] Fassig, O. L. The Daily Barometric Wave. Bull. No. 31, U. S. Weather Bureau. 8°. Washington, D. C., 1902, pp. 62-65, 12 pls.



THE DIURNAL BAROMETRIC WAVE.

(75TH MERIDIAN TIME.)

(Departures above and below the mean pressure of the day are expressed in thousandths of an inch of mercury.)

middle of the afternoon when the upward movement of the warm air may be assumed to be least impeded. In this connection, Fig. 17, on page 76, is significant, showing the average hourly rate of change of temperature for the year, compared with the curve representing the average hourly variation of pressure for the year.

As has already been stated above, the pressure-wave attains its greatest amplitude in the equatorial belt where the diurnal temperature changes are greatest, and over the continental masses north and south of the equator where the diurnal range of temperature is most marked. (See Plate I.)

According to Dr. Hann,[2] in seeking an explanation of the diurnal variations of the barometer: "We had better deal with the action of the sun on the upper strata of the atmosphere and treat this as the principal cause. The actinometrical observations show us that these upper strata absorb a considerable amount of heat. The diurnal heating action of the sun on the upper strata would harmonize far better with the general uniformity of the daily barometric oscillation along the different parallels of latitude as well as with its general independence of weather. We need not quite exclude local influences, but these seem to be more of a secondary character." This view is also held by Lord Kelvin, who seems to have been the first to suggest this explanation.

CORRECTIONS FOR REDUCTION TO TRUE MEAN PRESSURE.

The determination of the daily mean barometric pressure based on 24-hourly observations for ten years enables us to apply the necessary corrections to any given combination of daily observations in order to obtain a true mean. The following table contains the corrections for each month and for the year which must be applied to the series of observations made according to any of the five systems most frequently employed in barometric observations in this country. The average of the three observations made at 7 a. m., 2 p. m., and 9 p. m. approaches most nearly the true 24-hourly mean for the day, when the 9 p. m. observation is given double weight.

[2] Hann, J. The Theory of the Daily Barometric Oscillation. Quart. Journ. Roy. Met. Soc., London, 1899, p. 40.

CORRECTIONS FOR DIURNAL VARIATIONS OF THE BAROMETER.

(In Thousandths of an Inch.)

Hours of observation.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
$\frac{7\text{ A.}+2\text{ P.}+9\text{ P.}}{3}$	+4	+4	−1	−3	−3	−3	−4	−3	−2	+1	+2	+5	−1
$\frac{7\text{ A.}+2\text{ P.}+2(9\text{ P.})}{4}$	+2	+2	−1	−2	−1	−1	−2	−2	−2	+2	+1	+2	0
$\frac{7\text{ A.}+3\text{ P.}+11\text{ P.}}{3}$	+5	+5	+1	−1	0	−2	−2	−1	0	+2	+3	+5	+1
$\frac{10\text{ A.}+10\text{ P.}}{2}$	−20	−17	−18	−18	−15	−14	−15	−16	−18	−18	−18	−20	−18
$\frac{8\text{ A.}+8\text{ P.}}{2}$	−11	−11	−12	−11	−8	−8	−1	−8	−10	−14	−16	−12	−11

THE ANNUAL MARCH OF ATMOSPHERIC PRESSURE.

In order to determine the changes of pressure from day to day during the course of the year, the daily averages of the Baltimore observations covering a period of 30 years were reduced to what may be called normal values for each day of the year. In obtaining these normals the sea-level values were employed, but corrections for diurnal variation were not applied. The results are shown in Table V on page 45 and graphically by means of curve (d) of Plate III. This curve shows a fall in pressure from month to month from January to May. During May, June and July the pressure remains fairly uniform, followed by a comparatively rapid rise in August and September. During October there is a slight fall followed by a rise to January. The curve of daily changes does not, however, show a steady rise and fall from season to season.

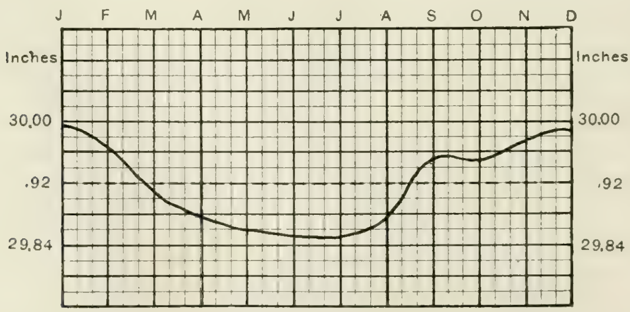
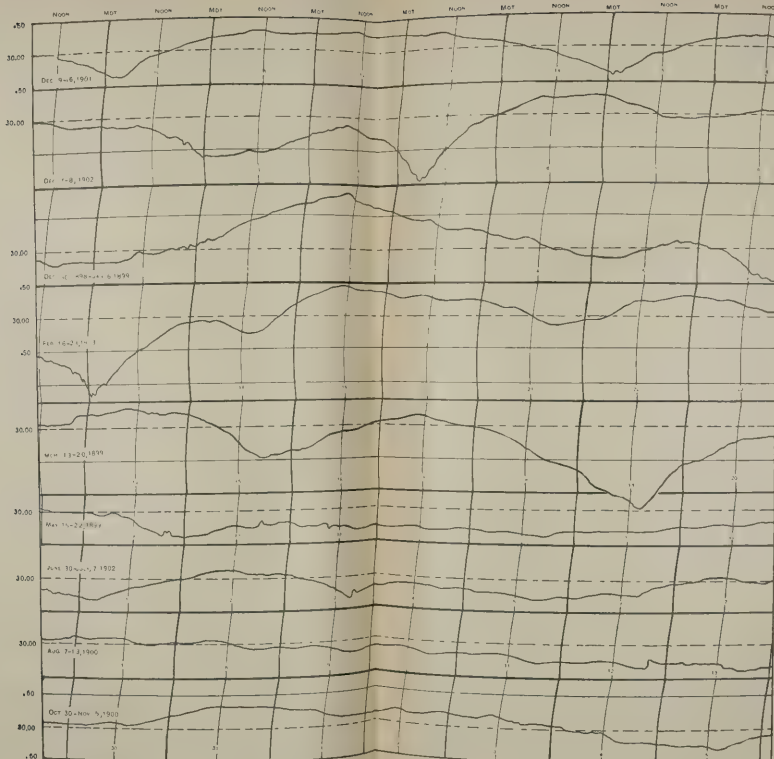


FIG. 6.—Mean Monthly Atmospheric Pressure. (See Table VI).



TYPICAL BAROGRAMS.

The progression is marked by successive waves varying in period from two to eight or ten days' duration, which persist even in the average daily values for 30 years. The variation from day to day is smallest

TABLE V.—MEAN DAILY BAROMETRIC PRESSURE,

Reduced to sea level.

[In inches and hundredths.]

29.00 Inches.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.16	1.14	1.07	1.03	1.00	1.01	1.04	1.00	1.09	1.11	1.11	1.16
2	1.13	1.21	1.03	1.00	.98	1.03	1.03	1.00	1.10	1.13	1.10	1.15
3	1.23	1.06	1.04	1.00	1.02	1.01	1.00	.99	1.08	1.11	1.13	1.13
4	1.17	1.10	1.06	.99	1.01	.99	.99	1.02	1.08	1.04	1.17	1.11
5	1.13	1.22	1.16	1.02	.99	.99	.99	1.04	1.09	1.05	1.15	1.08
6	1.04	1.17	1.13	1.04	.99	1.00	1.03	1.03	1.08	1.05	1.17	1.10
7	1.16	1.14	1.09	1.04	1.05	1.00	1.02	1.01	1.08	1.09	1.15	1.10
8	1.14	1.10	1.11	1.05	1.02	1.00	.98	1.01	1.10	1.09	1.08	1.14
9	1.06	1.11	1.02	1.01	1.01	.98	.96	1.01	1.12	1.12	1.06	1.16
10	1.10	1.17	1.05	1.00	1.01	1.00	.99	.99	1.12	1.11	1.05	1.13
11	1.13	1.13	1.08	1.02	1.01	1.01	1.00	1.00	1.11	1.11	1.09	1.10
12	1.16	1.08	1.01	1.08	1.00	1.01	1.00	1.00	1.08	1.11	1.13	1.13
13	1.14	1.04	1.03	1.03	.99	1.01	.96	1.00	1.07	1.08	1.13	1.09
14	1.17	1.14	1.10	.98	1.01	1.02	.98	.99	1.12	1.07	1.12	1.10
15	1.21	1.16	1.09	.96	.99	1.03	.96	1.02	1.10	1.13	1.10	1.12
16	1.18	1.12	1.04	1.03	1.00	1.03	.96	1.02	1.04	1.11	1.20	1.16
17	1.22	1.12	1.08	1.07	1.04	.97	.99	1.03	1.06	1.11	1.18	1.17
18	1.22	1.06	1.05	1.04	1.03	.97	.99	1.00	1.08	1.11	1.12	1.15
19	1.18	1.08	.96	1.02	.98	.98	1.00	1.00	1.02	1.11	1.04	1.22
20	1.13	1.08	.95	1.03	.99	.99	1.01	1.02	1.07	1.11	1.09	1.22
21	1.06	1.03	1.00	1.08	1.00	.96	1.01	.99	1.14	1.13	1.13	1.17
22	1.10	1.04	1.02	1.08	1.01	.95	1.01	1.01	1.12	1.13	1.14	1.15
23	1.16	1.08	1.03	1.03	1.03	1.00	1.02	1.03	1.09	1.07	1.06	1.15
24	1.13	1.16	1.09	1.03	1.01	1.00	1.02	1.02	1.13	1.12	1.12	1.16
25	1.14	1.05	1.09	1.03	.97	.98	1.00	1.01	1.12	1.14	1.12	1.15
26	1.11	1.08	.99	1.03	.97	.98	.97	1.05	1.07	1.08	1.11	1.05
27	1.10	1.15	.97	1.03	.94	.99	.98	1.06	1.09	1.04	1.11	1.06
28	1.09	1.14	.97	.96	.96	.95	1.00	1.07	1.12	1.07	1.13	1.17
29	1.12	.96	1.02	.96	1.01	.97	.98	1.04	1.09	1.05	1.12	1.11
30	1.17	....	1.04	1.00	.99	1.02	.98	1.02	1.10	1.09	1.17	1.17
31	1.07	....	1.02	...	.98	...	1.00	1.05	....	1.06	....	1.17
Average	1.14	1.11	1.04	1.02	1.00	0.99	0.99	1.02	1.09	1.09	1.12	1.14
Amplitude	.19	.18	.21	.12	.11	.08	.08	.08	.12	.10	.16	.17

Average for the year 30.062 inches. Average amplitude 0.05 inches.

Table V shows the average *sea-level* barometric pressure for each day of the year. The period of observation covers the 30 years from 1871-1900. The daily mean is based on three readings of the mercurial barometer at about 7 a. m., 3 p. m. and 11 p. m., from 1871 to June 1888, and on two readings at 8 a. m. and 8 p. m., from July 1888 to 1900. The correction for diurnal variation has not been applied, but this is extremely small for the observations made at 7 a. m., 3 p. m., and 11 p. m., and about +.01 inch for the series of readings at 8 a. m. and 8 p. m. The number 29.00 should be added to each of the figures in the body of the table. The monthly range of the mean daily pressure is indicated in the last line of the table. The figures of this table are also represented graphically in curve D of Plate 3.

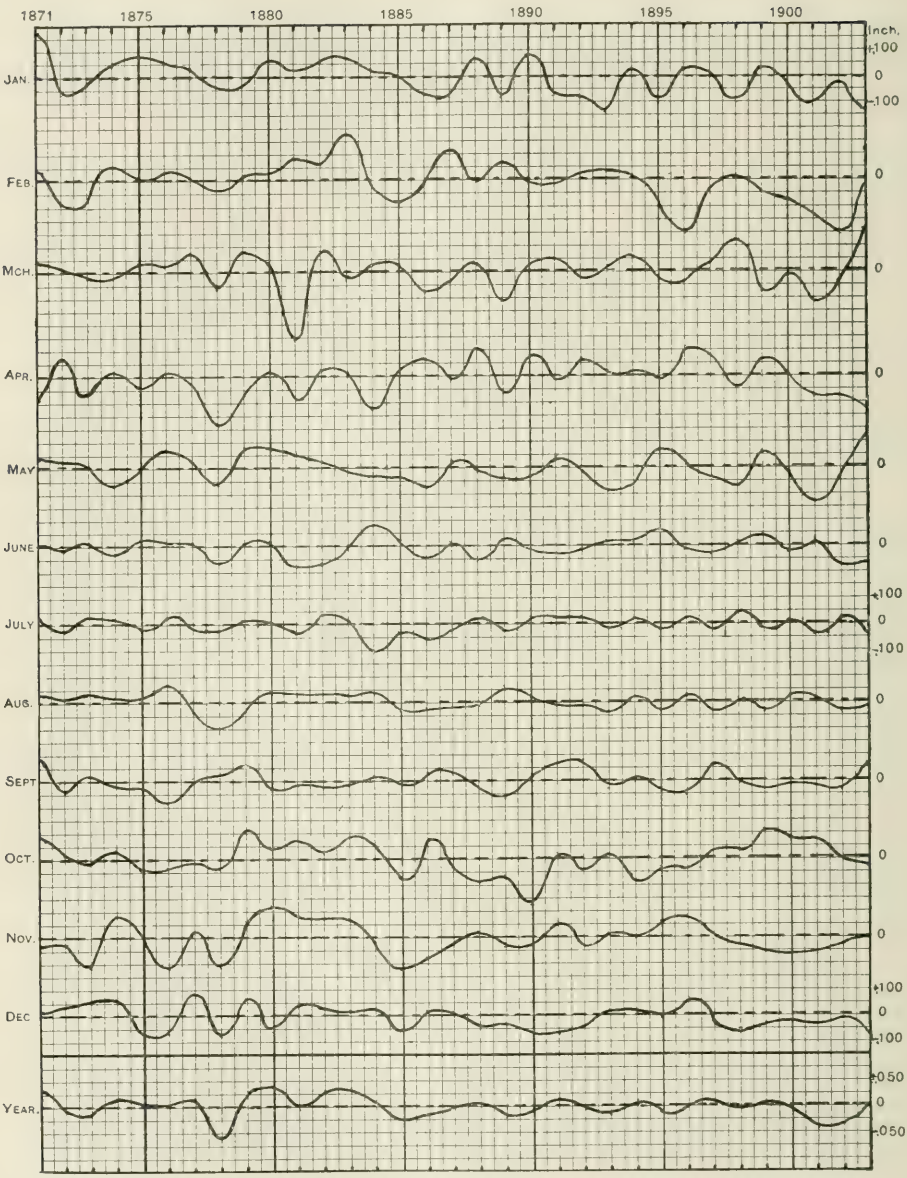


FIG. 7.—Variations in the Mean Monthly Pressure (Expressed as Departures from the Normal Values for the Month, in Thousandths of an Inch of Mercury). See Table VII.

during the summer months when it is generally less than 0.05 inch, and greatest in the winter months, when it rises to 0.10 inch, and, occasionally, to 0.15 inch. To what extent these irregular interdiurnal variations would be eliminated in a longer series of observations is a matter of conjecture. To a marked extent at least they are probably persistent and due to a periodic recurrence of certain types of weather at certain seasons of the year.

Of special interest is the comparatively rapid rise in pressure from August to September, and the arrested upward movement in October, more clearly shown in Fig. 6, constructed from monthly averages, than in the serrated curve of daily means.

The barometric waves of short period vary greatly in length and are not generally sharply defined, but in most instances they extend over a period of three and a half to four days, and are accompanied by inverse variations of temperature as is clearly shown in the temperature and pressure curves of Plate III. The individual features of these waves are shown in Plate II, in which actual tracings of the barograph are reproduced as representative types for the different seasons of the year. The great variability of barometric conditions in the winter months and the comparatively uniform conditions in the summer months are here shown in strong contrast. The curve representing the conditions for the week ending August 13th, 1900, is almost entirely free from irregular or non-periodic fluctuations, permitting the diurnal variations to be plainly recognized.

AVERAGE MONTHLY AND ANNUAL PRESSURE.

In an elaborate report on barometry,[3] Professor Bigelow has discussed in detail the reduction of barometric observations at Weather Bureau stations in the United States. In this report all observations from 1873 to 1899 have been reduced to the epoch of January 1, 1900. During this long period several different methods of reduction had been employed, resulting in series of observations not strictly comparable. In order to obtain comparable values all reductions were recomputed and

[3] Bigelow, F. H. The Reduction of Barometric Pressure Observations at Stations of the United States Weather Bureau. Vol. II of the Report of the Chief of the Weather Bureau for 1900.

TABLE VI.—MEAN MONTHLY STATION PRESSURE REDUCED TO THE WEATHER BUREAU SYSTEM FOR THE EPOCH JANUARY 1, 1900.

[Inches and thousandths.]

Lat. 39° 18′ N., Long. 76° 37′=5 hrs., 6 m. W. of Gr. Elevation above mean sea level 123.3 feet. Gravity corr. —.015.

29.000 inches.

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1873	0.971	0.886	0.884	0.808	0.866	0.859	0.888	0.916	0.959	0.934	0.865	1.039	0.906
1874	1.053	1.021	.879	.895	.796	.828	.871	.884	.940	.981	1.056	1.045	.937
1875	1.083	.986	.947	.833	.835	.874	.838	.873	.924	.900	.993	.925	.918
1876	1.044	1.014	.918	.888	.928	.868	.877	.936	.850	.906	.857	.928	.918
1877	1.042	.972	.974	.851	.884	.865	.830	.824	.952	.935	.996	1.077	.925
1878	.962	.831	.841	.689	.796	.788	.811	.761	.977	.902	.867	.911	.845
1879	.963	.974	.980	.809	.939	.853	.848	.831	1.012	1.043	1.040	1.050	.945
1880	1.060	.993	.943	.891	.929	.865	.852	.918	.918	.984	1.117	.928	.950
1881	1.023	1.063	.642	.786	.907	.773	.817	.894	.941	1.013	1.065	1.037	.913
1882	1.048	1.025	.983	.907	.879	.783	.894	.900	.928	.964	1.052	1.015	.948
1883	1.075	1.155	.873	.889	.839	.841	.856	.905	.934	1.036	1.052	1.004	.955
1884	1.025	.958	.909	.756	.824	.935	.744	.916	.968	1.016	.964	1.047	.922
1885	1.006	.875	.922	.906	.814	.877	.823	.832	.936	.871	.830	.911	.884
1886	.928	.957	.819	.949	.781	.829	.800	.841	.984	1.028	.898	1.004	.902
1887	.924	1.080	.852	.870	.884	.864	.830	.847	.976	.910	.953	.996	.916
1888	1.070	.958	.942	.983	.842	.801	.879	.859	.918	.848	.992	.941	.919
1889	.912	1.026	.783	.819	.816	.882	.828	.930	.881	.886	.932	1.022	.893
1890	1.080	.956	.908	.965	.819	.845	.880	.878	.971	.771	.936	.928	.911
1891	.921	.954	.949	.874	.901	.827	.888	.858	1.015	.955	1.036	1.054	.936
1892	.917	.992	.876	.942	.838	.847	.924	.865	1.024	.895	.938	.940	.916
1893	.847	.996	.920	.891	.759	.866	.834	.834	.910	.959	.980	1.004	.900
1894	1.023	.986	.963	.895	.792	.862	.870	.881	.949	.862	.976	1.000	.922
1895	.909	.879	.874	.869	.923	.920	.840	.828	.921	.914	1.033	.983	.908
1896	1.034	.764	.864	.981	.877	.839	.889	.901	.895	.910	1.063	1.053	.922
1897	1.009	.935	.938	.960	.821	.823	.814	.843	1.006	.990	.974	.947	.922
1898	.895	.969	1.073	.828	.793	.863	.899	.873	.942	.972	.953	.928	.916
1899	1.032	.918	.816	.939	.912	.902	.839	.831	.921	1.053	.926	.962	.921
1900	.951	.896	.888	.884	.840	.831	.856	.895	.941	1.029	.918	.966	.908
1901	.888	.828	.786	.801	.726	.858	.818	.883	.931	1.033	.918	.950	.869
1902	.975	.762	.855	.803	.894	.782	.871	.832	.904	.941	.951	.971	.879
1903	.866	.947	1.068	.761	.994	.792	.818	.855	1.009	.917	.964	.927	.910
Mean (1873-99).	.995	.968	.899	.877	.852	.851	.850	.869	.946	.942	.976	.988	29.917
Corr. for sea-level	.127	.137	.126	.133	.133	.139	.130	.136	.129	.138	.134	.137	.133
Mean, sea-level	1.122	1.105	1.025	1.010	.985	.990	.980	1.005	1.075	1.080	1.110	1.125	30.050

Table VI presents the average monthly and annual *station* pressures for each month and year from 1873 to 1899, as recorded in Professor Bigelow's Report on Barometry, with the addition of values for 1900 to 1903. All observations used in this table were reduced to the same plane (123 feet above mean tide), to the true mean of 24 hourly observations and corrected for the force of gravity at the Station. The values in the footings of the table are Professor Bigelow's "normals" for the period 1873 to 1899.

uniform corrections for gravity and for diurnal variation were applied by Professor Bigelow. The corrected monthly and annual means for Baltimore as given by Professor Bigelow are reproduced in Table VI on page 48, with the additional values for the years 1900 to 1903, similarly reduced. For the methods employed in the reduction of observa-

TABLE VII.—DEPARTURES FROM AVERAGE STATION PRESSURE.

[In thousandths of an inch.]

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1873	—.024	—.082	—.015	—.069	+.014	+.008	+.038	+.047	+.013	—.008	—.111	+.051	—.011
1874	+.058	+.053	—.020	+.018	—.056	—.023	+.021	+.015	—.006	+.039	+.080	+.057	+.020
1875	+.088	+.018	+.048	—.044	—.017	+.023	—.012	+.004	—.022	—.042	+.017	—.063	+.001
1876	+.049	+.046	+.019	+.011	+.076	+.017	+.027	+.067	—.096	—.036	—.119	—.060	+.001
1877	+.047	+.004	+.075	—.026	+.032	+.014	—.020	—.045	+.006	—.007	+.020	+.089	+.008
1878	—.033	—.137	—.058	—.188	—.056	—.063	—.039	—.108	+.031	—.040	—.109	—.077	—.072
1879	—.032	+.006	+.081	—.068	+.087	+.002	—.002	—.038	+.066	+.101	+.064	+.062	+.028
1880	+.065	+.025	+.044	+.014	+.077	+.014	+.002	+.049	—.028	+.042	+.141	—.060	+.033
1881	+.028	+.095	—.257	—.091	+.055	—.078	—.033	+.025	—.005	+.071	+.089	+.049	—.004
1882	+.053	+.057	+.084	+.030	+.027	—.068	+.044	+.031	—.018	+.022	+.076	+.027	+.031
1883	+.080	+.187	—.026	+.012	—.013	—.010	+.006	+.036	—.012	+.094	+.076	+.016	+.038
1884	+.030	—.010	+.010	—.121	—.028	+.084	—.106	+.047	+.022	+.074	—.012	+.059	+.005
1885	+.011	—.093	+.023	+.029	—.038	+.026	—.027	—.037	—.010	—.071	—.146	—.077	—.033
1886	—.067	—.011	—.080	+.072	—.071	—.022	—.050	—.028	+.038	+.086	—.078	+.016	—.015
1887	—.071	+.112	—.047	—.007	+.032	+.013	—.020	—.022	+.030	—.032	—.023	+.008	—.001
1888	+.075	—.010	+.043	+.106	—.010	—.050	+.029	—.010	—.028	—.094	+.016	—.047	+.002
1889	—.083	+.058	—.116	—.058	—.036	+.031	—.022	+.061	—.065	—.056	—.044	+.034	—.024
1890	+.085	—.012	+.009	+.088	—.033	—.006	+.030	+.009	+.025	—.171	—.040	—.060	—.006
1891	—.074	—.014	+.050	—.003	+.049	—.024	+.038	—.011	+.069	+.013	+.060	+.066	+.019
1892	—.078	+.024	—.023	+.065	—.014	—.004	+.074	—.004	+.078	—.047	—.038	—.048	—.001
1893	—.148	+.028	+.021	+.014	—.093	+.015	—.016	—.035	—.036	+.017	+.004	+.016	—.017
1894	+.028	+.018	+.064	+.018	—.060	+.011	+.020	+.012	+.003	—.080	.000	+.012	+.005
1895	—.086	—.089	—.025	—.008	+.071	+.069	—.010	—.041	—.025	—.028	+.057	—.005	—.009
1896	+.039	—.204	—.035	+.104	+.025	—.012	+.039	+.032	—.051	—.032	+.087	+.065	+.005
1897	+.014	—.033	+.039	+.083	—.031	—.028	—.036	—.026	+.060	+.048	—.002	—.041	+.005
1898	—.100	+.001	+.174	—.049	—.059	+.012	+.049	+.004	—.004	+.030	—.023	—.060	—.001
1899	+.037	—.050	—.083	+.062	+.060	+.051	—.011	—.038	—.025	+.111	—.050	—.026	+.004
1900	—.044	—.072	—.011	+.007	—.012	—.020	+.006	+.026	—.005	+.087	—.058	—.022	—.009
1901	—.107	—.140	—.113	—.076	—.126	+.007	—.032	+.014	—.015	+.091	—.058	—.038	—.048
1902	—.020	—.206	—.044	—.074	+.042	—.069	+.021	—.037	—.042	—.001	—.025	—.017	—.038
1903	—.129	—.021	+.169	—.116	+.142	—.059	—.032	—.014	+.063	—.025	—.012	—.061	—.007
Means	.995	.968	.899	.877	.852	.851	.850	.869	.946	.942	.976	.988	29.917
Dept.	.078	.051	—.018	—.040	—.065	—.066	—.067	—.048	.029	.025	.059	.071	

Table VII presents the average monthly and annual pressures expressed in terms of departures, in thousandths of an inch, from the normal values for the period 1873-1899. The normal for each month and for the year is shown in the first line of footings, and the departures of the monthly normals from the annual normal are shown in the last line. These departures are also graphically shown in Fig. 7 and Fig. 8.

tions and for further particulars in reference to the Baltimore pressure data the report of Professor Bigelow should be consulted, especially pages 176, 646 and 798.

In Table VII the mean monthly and annual pressures from 1873 to 1903 are given in terms of departures from the monthly and annual normal values. The normal monthly and annual pressures derived from the mean of the daily averages (see Table V) differ somewhat from those derived from Professor Bigelow's monthly means (see Table VI) after reducing the latter to sea-level. This discrepancy is due to the fact that the daily means were taken directly from the original record of observations of the Baltimore Office of the Weather Bureau to which the correction for diurnal variation had not been applied.

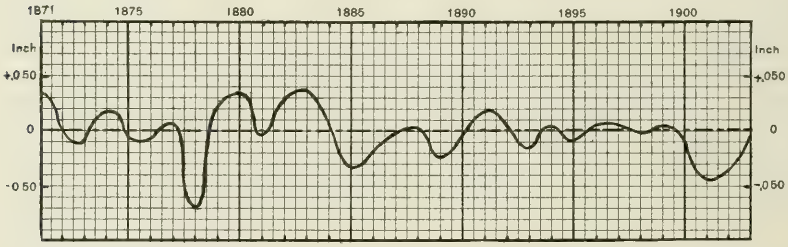


Fig. 8.—Annual Variations of Pressure Expressed as Departures from the Normal Value. (See Table VII.)

ANNUAL AND SECULAR VARIATIONS OF PRESSURE.

The average atmospheric pressure of a year is by no means a constant quantity. The fluctuations in value from year to year are sometimes considerable. This is most readily recognized when the variations are graphically presented as in Fig. 8 on page 50. Here the Baltimore observations are plotted in terms of annual departures from the normal value for the entire period from 1871 to 1903. The amplitude of fluctuation is expressed in thousandths of an inch. The resulting curve presents a series of waves or surges varying in amplitude from a few thousandths of an inch to nearly one-tenth of an inch. The period of oscillation also varies considerably, yet there is a remarkable uniformity in the length of these periods. Measuring from crest to crest and from hollow to hollow of these waves we have the following figures representing the periods in years and fractions:

	Number of Years.										Mean.
From crest to crest (from 1871).	4	4	4	4	5.5	4.5	4	3.5	3.5	5.5	4.2
From hollow to hollow (from 1873).	3.5	3.5	4	4	5	5	5	3	4	4	4.1

Since 1871, the beginning of the series of observations at Baltimore, no crest of a wave has been *below* the normal value for the entire period and no hollow has been *above* the normal level. In order to fall into harmony with this series the year 1903 should form the crest of a wave and be followed by approximately equal pressure in 1904 and lower pressure in 1905; but we must not overlook the fact that it is the unexpected which is most likely to follow a long-range forecast. The period from 1871 to 1903 includes ten waves with an average length from crest to crest, or from hollow to hollow, of slightly over 4 years, the limits of variability being three years and five years and a half.

A conspicuous feature of the annual variation of pressure at Baltimore is the abnormally low pressure of 1878. The departure in this year was nearly five times the average annual variability. Upon first examination it appears suspiciously large. It is, however, substantiated by similar departures, though not so marked, at stations in all parts of the United States. A few of the larger departures occurring in this year are here given:

DEPARTURES FROM NORMAL PRESSURE IN 1878.

Baltimore	—.072	New Orleans	—.068
Washington	—.057	St. Paul	—.052
New York	—.052	San Francisco	—.058
Cincinnati	—.080	Key West	—.059
St. Louis	—.049	Boston	—.056

The abnormally low pressure evidently extended over a very large territory in 1878. At Baltimore the pressure was decidedly below the average during every month of the year, excepting September, when it was but slightly above. Usually there is considerable fluctuation above and below the annual average during the course of the year. In 1901 the average pressure was also abnormally low, but not as low as in 1878.

Another marked feature of the curve is the steady diminution in the

amplitude of fluctuation from 1878 to 1900, diminishing with considerable uniformity from nearly one-tenth of an inch to about one-hundredth of an inch. Since 1900 the amplitude has again increased. The curve

TABLE VIII.—MAXIMUM STATION PRESSURES.

[In inches and hundredths.]

30 000 inches.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1875	.68	.57	.37	.32	.24	.13	.16	.20	.35	.48	.61	.61	.68
1876	.52	.85	.43	.43	.32	.12	.18	.16	.13	.36	.30	.59	.85
1877	.51	.50	.48	.26	.30	.19	.16	.16	.24	.41	.51	.51	.51
1878	.61	.26	.40	.20	.14	.11	.06	.10	.40	.29	.46	.49	.61
1879	.44	.70	.65	.37	.42	.22	.23	.13	.36	.75	.50	.56	.75
1880	.61	.58	.40	.32	.31	.22	.12	.34	.31	.41	.68	.47	.68
1881	.61	.73	.29	.30	.41	.12	.16	.22	.24	.52	.66	.57	.73
1882	.83	.68	.65	.43	.38	.18	.23	.26	.22	.29	.51	.48	.83
1883	.58	.73	.48	.37	.28	.40	.15	.20	.38	.56	.60	.57	.73
1884	.79	.68	.40	.16	.24	.41	.00	.24	.41	.53	.38	.59	.79
1885	.75	.41	.38	.50	.10	.21	.09	.15	.27	.24	.29	.70	.75
1886	.77	.49	.36	.43	.21	.18	.13	.25	.34	.41	.38	.46	.77
1887	.57	.81	.65	.55	.23	.26	.11	.19	.35	.39	.74	.83	.83
1888	.73	.57	.44	.51	.19	.16	.15	.19	.44	.31	.63	.53	.73
1889	.51	.78	.45	.39	.28	.35	.16	.18	.23	.28	.59	.73	.78
1890	.62	.47	.49	.54	.21	.28	.19	.15	.27	.24	.28	.51	.62
1891	.40	.56	.55	.34	.26	.10	.18	.08	.27	.38	.67	.51	.67
1892	.49	.57	.37	.35	.17	.11	.36	.04	.27	.31	.31	.46	.57
1893	.27	.64	.46	.31	.23	.16	.10	.07	.19	.37	.53	.71	.71
1894	.48	.66	.45	.28	.30	.15	.06	.05	.38	.23	.59	.27	.66
1895	.34	.40	.38	.48	.17	.32	.10	.12	.23	.40	.51	.60	.60
1896	.38	.39	.49	.38	.24	.12	.22	.20	.22	.36	.62	.78	.78
1897	.59	.51	.58	.50	.28	.13	.17	.07	.27	.48	.46	.42	.59
1898	.40	.50	.52	.12	.16	.15	.20	.12	.29	.33	.42	.46	.52
1899	.84	.56	.30	.27	.20	.11	.12	.11	.29	.41	.40	.49	.84
1900	.44	.58	.47	.30	.21	.04	.08	.18	.20	.30	.52	.36	.58
1901	.61	.23	.22	.33	.03	.08	.04	.06	.33	.47	.34	.38	.61
1902	.79	.24	.32	.18	.26	.35	.11	.11	.32	.43	.38	.56	.79
1903	.42	.49	.43	.31	.34	.18	.35	.27	.30	.21	.57	.46	.57
Extremes	.84	.85	.65	.55	.42	.41	.36	.34	.44	.75	.74	.83	.85

Table VIII presents the highest *station* pressure observed at any of the regular hours of observation for each month and for the entire year, from 1875 to 1903, together with the absolute extremes for each month and for the entire period of observation. The absolute extremes are also indicated in Fig. 9 curve (a). The number 30.00 should be added to each of the figures in the table.

also shows some suggestions of a wave of greater period. From 1885 to 1899 there seems to have been a gradual rise in pressure. The Baltimore series of observations is, however, too short to place much reliance upon the evidence of a long period of variation.

THE AVERAGE VARIABILITY OF PRESSURE.

Some interesting facts regarding the variability of pressure conditions are revealed in Table VII showing the departures of monthly average pressures from 1873 to 1903. The month of greatest variability is March

TABLE IX.—MINIMUM STATION PRESSURES.

[In inches and hundredths.]

29.000 inches.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1875	.55	.36	.36	.52	.35	.66	.61	.64	.59	.49	.52	.37	.35
1876	.49	.20	.21	.48	.58	.64	.72	.72	.18	.49	.48	.01	.01
1877	.31	.38	.02	.36	.46	.52	.64	.63	.66	.29	.38	.29	.02
1878	.39	.28	.18	.22	.55	.40	.55	.56	.49	8.74	8.90	8.65	28.65
1879	.29	.43	.34	.36	.64	.44	.51	.59	.65	.54	.45	.57	.29
1880	.48	.27	.26	.52	.73	.59	.59	.66	.59	.42	.41	.59	.26
1881	.26	.32	.00	.46	.56	.54	.60	.60	.77	.50	.64	.34	.00
1882	.29	.26	.48	.31	.46	.47	.57	.56	.50	.74	.69	.60	.26
1883	.54	.65	.29	.56	.29	.60	.64	.61	.50	.44	.69	.48	.29
1884	.17	.25	.45	.14	.57	.63	.55	.64	.66	.66	.42	.45	.14
1885	.40	.19	.53	.46	.44	.43	.61	.52	.42	.02	.53	.25	.02
1886	8.91	.24	.20	.29	.47	.47	.63	.59	.62	.73	.41	.44	28.91
1887	.37	.30	.35	.22	.52	.55	.62	.64	.54	.48	.39	.32	.22
1888	.62	.44	.34	.48	.59	.63	.58	.35	.60	.42	.38	.85	.34
1889	.13	.47	.35	.22	.63	.59	.60	.66	.47	.44	.40	.54	.13
1890	.63	.54	.38	.42	.54	.67	.64	.64	.82	.35	.60	.36	.35
1891	.12	.37	.37	.38	.66	.53	.61	.56	.76	.55	.28	.48	.12
1892	.14	.17	.16	.52	.44	.50	.63	.59	.59	.47	.47	.41	.14
1893	.07	.12	.27	.35	.26	.48	.56	.39	.54	.01	.60	.43	.01
1894	.22	.39	.50	.34	.40	.52	.58	.66	.55	.20	.54	.22	.20
1895	.17	.22	.35	.22	.48	.64	.56	.61	.60	.52	.35	.31	.17
1896	.45	8.81	8.99	.57	.55	.43	.59	.70	.54	.55	.50	.61	28.81
1897	.54	.43	.25	.47	.40	.57	.50	.55	.70	.54	.28	.36	.25
1898	.29	.26	.69	.33	.36	.52	.61	.68	.59	.52	.29	.11	.11
1899	.18	.39	.04	.48	.56	.66	.68	.60	.57	.35	.31	.03	.03
1900	.22	.14	.22	.54	.30	.57	.46	.75	.55	.72	.19	.30	.14
1901	.14	.44	.21	8.97	.42	.63	.66	.72	.54	.53	.25	.38	28.97
1902	.32	.14	.19	.12	.58	.34	.64	.59	.64	.43	.30	.20	.12
1903	.21	.17	.46	.21	.76	.50	.49	.61	.62	.48	.52	.26	.17
Extremes	8.91	8.81	8.99	8.97	.26	.34	.46	.35	.18	8.74	8.90	8.65	28.65

Table IX presents the lowest *station* pressure observed at any of the regular hours of observation for each month and for the entire year, from 1875 to 1903, together with the absolute extremes for each month and for the entire period of observation. The absolute extremes are also indicated in Fig. 9 curve (e). The number 29.00 should be added to all fractional numbers in the table.

with an extreme limit of 0.431 inch and an average variability of 0.058 inch. The month of most uniform pressure is June with an extreme amplitude of 0.162 inch and an average variability of 0.029 inch. The month of December shows a remarkable freedom from extreme fluctua-

tions, being next to June in this respect, while at the same time exhibiting a fairly large average variability. In the following table the variability of the average monthly and annual pressure at Baltimore is shown by means of the average plus or minus departures from the normal monthly and annual values, the greatest plus and minus departures and the extreme variations of the monthly and annual values.

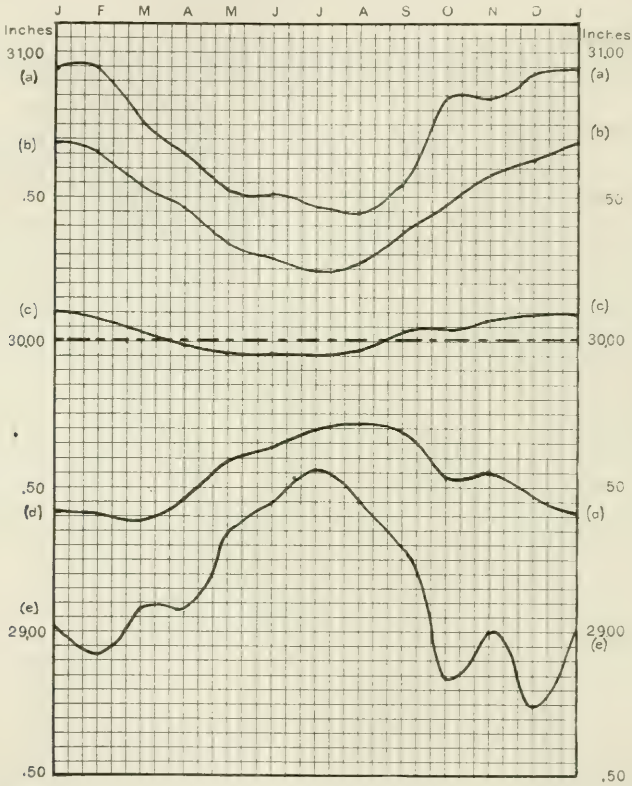


FIG. 9.—Monthly Means and Extremes of Pressure. (See Tables VIII, IX and X.)

VARIABILITY OF PRESSURE CONDITIONS AT BALTIMORE.

(Expressed as departures from the normal values in thousandths of an inch.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Greatest plus departure (+).	88	187	174	106	142	84	74	67	78	111	141	89	38
Greatest minus departure (−).	148	206	257	188	126	78	106	108	96	171	146	77	72
Extreme amplitude.	236	393	431	294	268	162	18	175	174	282	287	166	110
Average departure (±).	59	55	58	54	45	29	30	33	32	55	59	46	15

The negative departures are far more marked than the positive. Only in May, June and November have the plus departures exceeded the minus. This contrast is particularly strong in the figures representing

TABLE X.—SUMMARY OF PRESSURE CONDITIONS.

[In inches and thousandths.]

	Monthly Means.							Mean Monthly and Annual Extremes.					Absolute Extremes.				
	Means. 1873 to 1899	Highest and Lowest Means as Departures from Normal. 1873-1903.				Range.	Mean Variability.	1875-1903.					1875-1903.				
								Average of Extremes.		Departures from Normal.		Mean range.	Max.	Year.	Min.	Year.	Range.
		Highest.	Year.	Lowest.	Year.			Highest.	Lowest.	Highest.	Lowest.		30.000+		28.000+		
	29.000+							30.000+	29.000+								
Jan....	.995	+.088	1875	—.148	1893	.236	.059	.572	.307	+.577	—.688	1.265	.843	1899	.908	1886	1.935
Feb. ..	.968	.187	1883	—.206	1902	.393	.055	.557	.298	.589	—.670	1.259	.849	1876	.809	1896	2.040
Mar. ..	.899	.174	1898	—.257	1881	.431	.058	.443	.291	.544	—.608	1.152	.650	1887	.992	1896	1.658
Apr. ..	.877	.106	1888	—.188	1878	.294	.054	.353	.363	.476	—.514	.990	.550	1887	.969	1901	1.581
May...	.852	.142	1903	—.126	1901	.268	.045	.245	.502	.393	—.350	.743	.424	1879	1.257	1893	1.167
June..	.851	.084	1884	—.078	1881	.162	.029	.191	.542	.340	—.309	.649	.414	1884	1.345	1902	1.069
July ..	.850	.074	1892	—.106	1884	.180	.030	.151	.594	.301	—.256	.557	.359	1892	1.457	1900	.902
Aug...	.869	.067	1876	—.108	1878	.175	.033	.159	.608	.290	—.261	.551	.342	1880	1.350	1888	.992
Sept...	.946	.078	1892	—.096	1876	.174	.032	.293	.581	.347	—.365	.712	.440	1888	1.181	1876	1.259
Oct....	.942	.111	1899	—.171	1890	.282	.055	.381	.435	.439	—.507	.946	.752	1879	.739	1878	2.013
Nov...	.976	.141	1880	—.146	1885	.287	.059	.498	.420	.522	—.556	1.078	.740	1887	.902	1878	1.838
Dec. ..	.988	.089	1877	—.077	1878	.166	.046	.540	.352	.552	—.636	1.188	.830	1887	.648	1878	2.182
Year..	.917	.038	1883	—.072	1878	.110	.015	.694	.120	.777	—.797	1.574	.849	1876	.648	1878	2.201

Table X presents a summary of pressure conditions, derived mostly from the preceding tables. It shows the mean monthly values; the highest and lowest mean values, with year of occurrence and range; the mean variability of the monthly means; the mean monthly and annual extremes, with their respective departures from the normal value, and their ranges; the amount and year of occurrence of the absolute extreme values, and the absolute range of pressure for each month and year. Much of the data contained in this table is also shown graphically in Fig. 9.

the annual departures. The *extreme* amplitudes, or the differences between the highest and lowest average monthly values are about six times larger than the *average* plus or minus departures. This ratio is remarkably constant throughout the year, excepting the months of December and January when the ratio falls to 4.

EXTREMES OF PRESSURE.

The extreme range of the barometer at Baltimore from 1871 to 1903, according to the official records of the United States Weather Bureau, is 2.20 inches. The highest *observed* reading, namely 30.85 inches, occurred on February 5, 1876, and the lowest, 28.65 inches, on December 10, 1878. The barometer seldom falls below 29.00 inches in the Middle Atlantic states; since 1875 a lower reading has been observed at Baltimore but once in each of the months of January, February, March, April, October, November, and December, and never in the months of May to September. The very low pressures occur only in connection with a severe cyclonic storm of the winter type, or in connection with tornadoes. In the center of the extremely limited area of a tornado the barometer has fallen to 27.00 inches or less for a few minutes, but Baltimore has fortunately been visited but two or three times in the past 30 years or more by these fierce and destructive storms, and then only by a comparatively mild type. Of the seven occasions referred to above on which the barometer fell below 29.00, three occurred in the year 1878, a year remarkable for low pressures, two in 1896, one in 1886, and one in 1901.

The abnormally high pressures likewise occur in the winter months only, the most marked of them in connection with the intenser types of cold waves. The highest observed reading of the barometer occurred during the cold wave of February, 1876, when the pressure rose to 30.85 inches. A detailed record of the highest and lowest observed pressures for each month and for the year is given in Tables VIII and IX on pages 52 and 53. For a summary of averages and extreme conditions of pressure reference may be made to Table X. In Figure 9 some of the chief features of this table are graphically shown.

TEMPERATURE OF THE ATMOSPHERE.

Introduction.—There are certain factors which, in the long run, determine the average temperature of every locality. Of these the latitude, the position of the place with reference to large land and water areas, the height above sea-level, the nature of the soil, and other factors of minor importance are constant and tend to give to a place a fixed mean temper-

ature. Other factors, as wind direction, amount of cloudiness, etc., vary greatly from day to day and from season to season, and tend to produce a variable mean temperature. In some localities, within the tropics for example, these variable factors become fairly constant, and enable us to determine the average temperature by means of a comparatively short period of observations. In others the variable factors are large, as in the temperate zones, especially in the usual paths of cyclonic disturbances. In such regions a long series of observations is often necessary to determine the average temperature conditions to within 1° or less. In the smaller islands of the tropics five or six years of carefully made temperature records will yield an annual mean value with a probable error not greater than one-tenth of a degree. In the temperate regions an equally accurate annual mean may require observations covering a period of 50 to 100 years. In the long run the effect of the variable climatic factors is eliminated and a given locality secures a position upon the normal temperature chart, due to its geographical and topographical position and the nature of the soil. Baltimore occupies a middle position on the climatic chart with average annual and summer temperatures 3° or 4° below the average for the entire globe, and a winter temperature about 10° below. The city lies between a region of equable temperatures, the ocean, and one of great variability, the north continental area. The factor to which is due most of the changeable character of the weather of Baltimore, causing a variability greater than is its due on account of latitude, is its proximity to the great transcontinental storm paths. Baltimore is within the influence of the barometric depressions which continually pass from the northwest, across the Lake region and the New England states, and which are accompanied by rapid changes in wind direction from the warm southerly to the colder west and northwest winds.

Average Temperatures.

For purposes of comparison it is essential to have a standard of reference. In discussing temperature conditions the standard of value is usually assumed to be the average daily temperature. This daily average is derived from observations made hourly throughout the day and night. Approximate averages are obtained from two or more observations made at

such hours of the day as to give a value more or less closely agreeing with that derived from hourly observations. Experience has shown that fairly accurate daily averages may be obtained by noting the temperature at 7 a. m., 3 p. m., and 9 p. m., or 7 a. m., 3 p. m., and 11 p. m., or 10 a. m., and 10 p. m., or 8 a. m., and 8 p. m., or from the highest and lowest temperatures recorded during the day. In later years automatically recording instruments have largely displaced direct observations permitting us to obtain a daily mean temperature to any desired degree of accuracy with comparatively little personal attention. Monthly, seasonal, and annual means are in turn derived from the daily means.

In the discussion of temperatures in succeeding pages we must not lose sight of the nature of average values. They are not real values in the sense of occurring in nature. When we say that the average temperature on the 4th of July in Baltimore is 79°, we mean that by adding together the hourly temperatures on the 4th of July for a great many years and dividing by the total number of hours we obtain the value 79°. This may never have been the real average value for the day on any 4th of July. It is simply an arithmetical mean; the real temperatures of the day may have had any value from 60° to 100° or more.

Average values are sometimes very misleading if sole reliance be placed upon them to characterize the temperature conditions of a day or a season. Two seasons may have the same mean temperature and yet be totally different in character. The summer of 1898 left the impression of an unusually warm season. The official records show a temperature very near the average of a period of thirty years (76°). The average may be obtained from any one of a large series of combinations, and our general impression of the character of the season will be determined by the particular combination of weather experienced. The temperature may remain uniformly near the average throughout the season; there may be excessively high temperatures of short duration combined with longer periods of moderately low temperatures; or excessively low temperatures combined with longer periods of moderately high; or there may be very high combined with very low temperatures, etc. All of these combinations *may* produce a "normal" average, but the personal effect will be different in each instance, and give rise to a variety of opinions as to the

character of the season. Disregard of such considerations frequently leads to unfavorable criticism of official records. Hence the figure representing the average temperature of a period is not of itself a safe criterion of the temperature conditions; the variability of temperature is an essential factor in revealing the character of the period.

The Normal Hourly Temperature.

The most familiar, and at the same time most regular, feature of changes in the weather is the rise and fall of temperature between sunrise and sunset. Like the pressure change it is most regular in the tropical regions, and diminishes in amplitude with distance from the equator until it disappears by merging into the annual change within the Arctic Circle. As the amplitude of variation depends very largely upon the character of the surface upon whch the rays of the sun fall, there are marked departures from the general law of decrease in amplitude with increased latitude. Over a water surface the daily changes are small; over the interior of the continental areas, especially over sandy soils and in a dry atmosphere, they are enormously increased. The difference between the highest and lowest temperature recorded during an average day a few feet above the surface of mid-ocean is not ordinarily more than 1° or 2°, owing to the relatively large absorbing power of water, and to the large quantity of heat employed in the conversion of water into vapor—the latent heat of evaporation. The surface of the soil, especially when unprotected by vegetation, is rapidly warmed by the sun's rays and attains a high temperature, owing to its comparatively low specific heat. The atmosphere above such surfaces is in turn heated by contact and by convection currents. In consequence the difference between midday and night temperatures over land surfaces is many times larger than over water surfaces. For any given locality the diurnal variation also varies with the season of the year, following the changes in the altitude of the sun, and hence is greatest in the summer months and least in the winter months.

The Baltimore hourly observations of temperature extend over a period of ten years, affording ample data for determining all phases of the diurnal variation. The tracings of the Richard thermograph were cor-

rected at four points each day by means of direct observation of a mercurial thermometer at 8 a. m., and 8 p. m., and by readings of the maximum and minimum points reached by a mercurial maximum and an alcohol minimum thermometer. The average values for the ten years

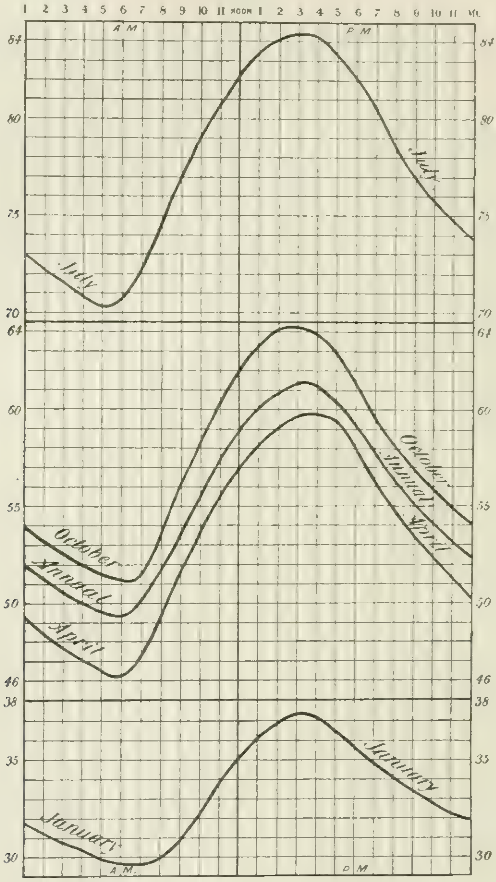


Fig. 10.—Mean Hourly Temperature. (See Table XI.)

for each hour of the day, for each month, and for the year are given in Table XI, and in Fig. 10 and Fig. 11.

The details of changes in temperature from hour to hour are best shown in tabular form from which the exact value for each hour may be readily taken. The graphic form, however, presents advantages in afford-

TABLE XI.—MEAN HOURLY TEMPERATURE.

Hours.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1 A. M.	31.4	29.9	40.1	49.1	59.6	68.0	72.9	71.3	65.2	53.9	44.1	35.0
2	31.0	29.4	39.4	48.3	58.8	67.2	72.2	70.7	64.6	53.3	43.7	34.5
3	30.6	28.9	38.8	47.6	58.1	66.4	71.4	69.9	63.8	52.7	43.2	34.2
4	30.2	28.5	38.3	47.1	57.5	65.8	70.8	69.3	63.1	52.1	42.7	33.8
5	29.8	28.1	37.9	46.5	57.0	65.2	70.3	68.7	62.5	51.7	42.3	33.4
6	29.6	27.9	37.6	46.4	57.4	66.1	70.6	68.8	62.2	51.3	42.0	33.0
7	29.4	27.8	37.8	47.4	59.0	68.2	72.4	70.4	63.1	51.6	41.9	32.9
8	29.7	28.4	38.8	49.5	61.3	70.5	74.7	73.0	65.7	53.6	42.8	33.3
9	30.6	29.7	40.5	51.7	63.4	72.8	77.2	75.4	68.0	56.0	44.8	34.5
10	32.0	31.3	42.2	53.7	65.2	74.6	79.1	77.7	70.5	58.4	46.7	36.0
11	33.7	33.1	44.0	55.6	67.1	76.3	80.9	79.8	72.6	60.6	48.6	37.9
Noon	35.0	34.6	45.7	57.1	68.4	77.5	82.4	81.0	74.2	62.3	50.2	39.4
1	36.0	35.8	47.0	58.2	69.5	78.7	83.4	82.1	75.3	63.4	51.4	40.7
2	36.8	36.9	48.2	59.0	70.5	79.6	84.0	82.8	76.1	64.2	52.0	41.6
3	37.2	37.2	48.7	59.6	70.7	79.9	84.2	82.9	76.4	64.4	52.2	42.0
4	37.0	37.2	48.8	59.6	70.7	79.8	84.1	82.6	76.3	64.0	51.6	41.5
5	36.2	36.5	48.0	59.0	70.2	78.9	83.1	81.6	75.1	62.8	50.4	40.5
6	35.4	35.3	47.0	57.9	69.0	77.6	81.8	80.5	73.4	61.2	49.2	39.5
7	34.5	34.4	45.6	56.2	67.0	75.7	80.1	78.8	71.6	59.5	48.1	38.6
8	34.0	33.6	44.5	54.9	65.2	74.1	78.3	77.0	70.2	58.1	47.3	37.9
9	33.0	32.8	43.4	53.6	63.7	72.6	76.6	75.6	68.6	56.9	46.4	37.1
10	32.8	32.2	42.5	52.5	62.6	71.3	75.6	74.4	67.5	55.9	45.7	36.5
11	32.1	31.6	41.7	51.6	61.5	70.2	74.5	73.2	66.8	55.0	44.9	35.9
Midnight	31.8	31.1	40.9	50.5	60.9	69.2	73.7	72.2	65.7	54.2	44.2	35.2
Means	32.9	32.2	42.8	53.0	63.9	72.8	77.3	75.8	69.1	57.4	46.5	36.9

MEAN HOURLY TEMPERATURE.

	Spring.	Summer.	Autumn.	Winter.	Year.
1 A. M.	49.6	70.7	54.4	32.1	51.7
2	48.8	70.0	53.9	31.6	51.1
3	48.2	69.2	53.2	31.2	50.5
4	47.6	68.6	52.6	30.8	49.9
5	47.1	68.1	52.2	30.4	49.4
6	47.1	68.5	51.8	30.2	49.4
7	48.1	70.3	52.2	30.0	50.2
8	49.9	72.7	54.0	30.5	51.8
9	51.9	75.1	56.3	31.6	53.7
10	53.7	77.1	58.5	33.1	55.6
11	55.6	79.0	60.6	34.9	57.5
Noon	57.1	80.3	62.2	36.3	59.0
1	58.2	81.4	63.4	37.5	60.1
2	59.2	82.1	64.1	38.4	61.0
3	59.7	82.3	64.3	38.8	61.3
4	59.7	82.2	64.0	38.6	61.1
5	59.1	81.2	62.8	37.7	60.2
6	58.0	80.0	61.3	36.7	59.0
7	56.3	78.2	59.7	35.8	57.5
8	54.9	76.1	58.5	35.2	56.3
9	53.6	74.9	57.3	34.3	55.0
10	52.5	73.8	56.4	33.8	54.1
11	51.6	72.6	55.6	33.2	53.2
Midnight	50.8	71.7	54.7	32.7	52.5
Means	53.2	75.3	57.7	34.0	55.0

Table XI shows the mean temperature for each hour of the day, based on the continuous record of a Richard thermograph for the ten-year period ending December 31, 1902. The thermograph record was corrected daily by direct observations of a mercurial thermometer at 8 a. m. and 8 p. m., and by the readings of a maximum and a minimum self-registering thermometer. The annual mean (55.0°) is the average value of over 87,000 hourly observations, and may be regarded as a true normal value for the period covered by the observations. The same results are graphically shown in Fig. 10, for January, April, July, October, and the year, and in Fig. 11, for all the months of the year.

ing a readier means of observing the relative changes from hour to hour and the distribution of temperature within the day, the month, and the year. The method of presentation employed in Fig. 11 is particularly well adapted to a rapid survey of the hourly and seasonal distribution. In construction it resembles the maps prepared for showing the varying topography of an area. In place of the meridians of longitude and parallels of latitude to arrive at the geographical position of a given locality, we have vertical lines to represent the hours of the day and horizontal lines for the months of the year, the intersection of which gives us the

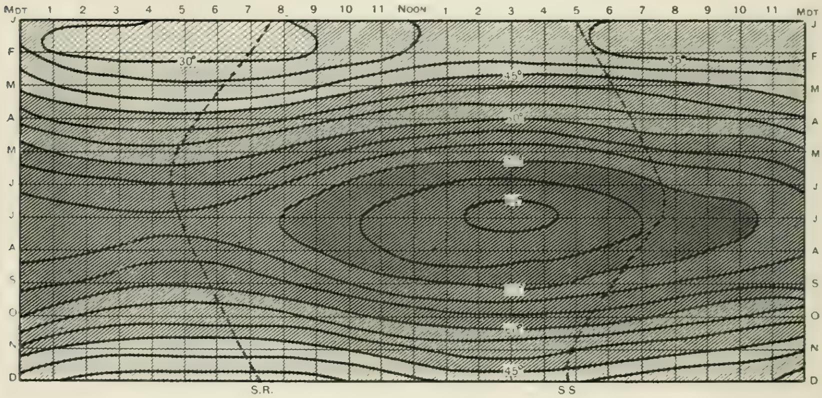


FIG. 11.—Isopleths of Hourly Temperature.

Fig. 11 shows the average distribution of temperature throughout the day and year, based on observations of ten years of hourly readings of the thermograph. The hours of the day are indicated by the upper line of figures, while the marginal letters indicate the months of the year. The line enclosing the area of lightest shading defines the time of occurrence of the lowest temperature of the year and day; rise in temperature is indicated by increase in the intensity of shading. The diagram indicates that the lowest temperatures of the year occur in the early morning hours of January and February, and that the highest occur in the early afternoon hours of July, based on the average of a long series of years. The curved lines show the hours of the day and the months of the year when the average readings of the thermometer are equal; these lines are called chrono-isotherms, or, isopleths of temperature. The dotted lines marked S.R. and S.S. show the time of sunrise and sunset. See also Table XI.

time sought. In place of the contour lines, or lines of equal elevation of the topographic map, we have lines of equal temperature (or isopleths of temperature as they are called when used in this manner) projected upon the plane of the time lines. The rapid detection of the diurnal and annual distribution of temperature is further facilitated by means of a system of shaded areas, increase in the intensity of the shade signifying

increase in temperature. Consulting Fig. 11 we find that for Baltimore a temperature of 84° is limited, under average conditions, to the hours from 2 p. m. to 4 p. m., during the month of July; that the temperature of 75° occurs, on the average, from June, between the hours of 10 a. m. and 7 p. m., to September, between 1 p. m. and 5 p. m., etc. In the winter months the line of 32°, or freezing weather for example, is limited, on the average, to the months of January and February from midnight to 10 a. m. We see that the average summer temperature of 76° extends from June to September during the middle hours of the day, while the average winter temperature of 36° is confined to the night and morning hours of December, January and February, and to a few of the early morning hours of March. The lowest temperature of the day occurs, on the average, just before sunrise and hence varies with the advance and retreat of the sun. The time of occurrence of the highest temperature varies less with the season, occurring throughout the year between 3 p. m. and 4 p. m., excepting the month of November when the highest temperature of the day occurs at about 2.30 p. m.

The diurnal variation of temperature is represented by a simple curve which rises steadily from a minimum point just before sunrise, attains a maximum in the early afternoon hours, and then descends without interruption to the early morning minimum. In this respect it differs from the curve representing the diurnal variation of the barometer which, as we have seen, has a double period, with primary and secondary maximum and minimum points.

Phases of the Diurnal Variation.

The principal phases of the diurnal variation of temperature are presented in Table XII, containing a summary of the average time of occurrence of the minimum, the maximum, and the mean temperature for the day, and the varying interval between the occurrence of the minimum and maximum points. In the months of May and June the lowest temperature of the day occurs at 5.05 a. m., 75th meridian time, which is six minutes faster than Baltimore local time; the time advances steadily to 6.50 a. m. in January, returning again to 5.05 a. m. in May. The maximum of the day shows less variation in time of occurrence. From

January to May it remains at about 3.25 p. m., then occurs successively earlier in the day until November, when a maximum is attained at 2.25 p. m. It seems rather remarkable that the maximum temperature of the day should appear earliest in the month of November. The *average* temperature occurs first at about 9 a. m. in the summer months and at 10.30 a. m. in the winter months, and again between 8.30 p. m. and 9.00 p. m. in summer, and about 10.00 p. m. in the winter months, excepting

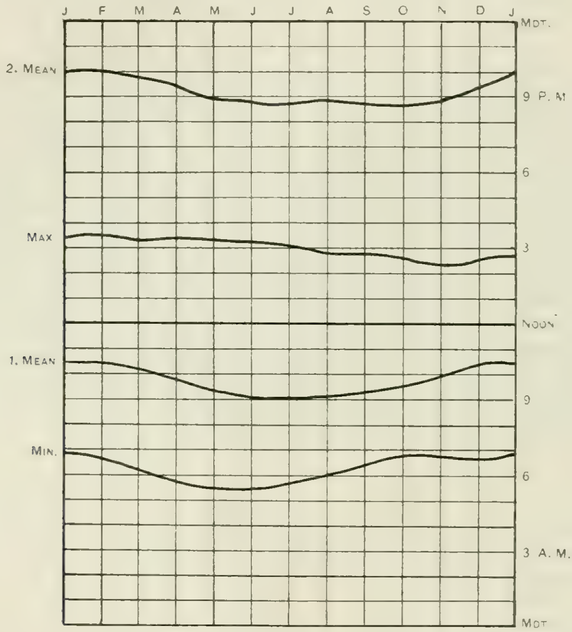


FIG. 12.—Principal Phases of Diurnal Variation of Temperature.

Fig. 12 shows the time of occurrence of the highest and lowest points indicated by the thermometer on an average day for each month; also the morning and afternoon hours when the mean temperature of the day is most likely to occur. See also Table XII.

December, when it occurs as early as 9.20 p. m. The amplitude of variation, or the difference between the daily maximum and daily minimum temperature, is greatest in the month of June (14°.7) and is smallest in the month of January (7°.0). (See Fig. 12.)

The temperatures thus far discussed are average values for a period of ten years. When we examine into the time of occurrence of the principal phases of the diurnal march of temperature more closely we find

a wide divergence from the average time of occurrence as recorded in preceding paragraphs. The limits of variability in the average time for a single month are shown in the following tabular statement containing the hour and the frequency of occurrence of each phase in each month of the ten-year period.

TABLE XII.—TEMPERATURE PHASES.

	Minimum. Frequency. a. m.				Minimum. Average time.	1st Mean. Frequency. a. m.			1st Mean. Average time.	Maximum. Frequency. p. m.					Maximum. Average time.	2nd Mean. Frequency. p. m.				2nd Mean. Average time.	Total Amplitude.
	5	6	7	8		9	10	11		1	2	3	4	5		8	9	10	11		h-m.
January	2	3	7	2	6:50	..	5	5	10:30	..	1	7	5	..	3:20	..	4	5	1	9:50	8-30
February	3	4	7	1	6:30	..	5	5	10:30	..	1	5	4	1	3:30	..	2	5	3	10:00	9-00
March	..	8	3	..	6:15	..	6	4	10:20	..	1	4	6	..	3:25	..	4	6	..	9:40	9-10
April	3	7	..	..	5:40	3	7	..	9:40	..	..	7	6	..	3:30	..	3	7	..	9:30	9-50
May	10	1	..	..	5:05	7	3	..	9:20	1	1	6	5	..	3:25	..	9	1	..	8:50	10-20
June	10	1	..	..	5:05	9	1	..	9:00	..	2	7	4	..	3:10	1	8	1	..	8:50	10-05
July	10	2	..	..	5:10	9	1	..	9:05	1	2	2	5	..	3:05	2	8	..	..	8:35	9-55
August	8	5	..	..	5:25	9	1	..	9:10	..	4	6	1	..	2:45	1	9	..	..	8:50	9-20
September	2	9	..	..	5:50	4	6	..	9:25	..	4	4	2	..	2:50	2	8	..	..	8:40	9-00
October	..	9	1	..	6:05	4	6	..	9:35	..	4	8	..	..	2:40	3	7	..	..	8:35	8-35
November	1	6	7	..	6:25	1	8	1	9:55	1	5	6	..	..	2:25	2	5	3	..	8:55	8-00
December	..	4	9	..	6:40	..	6	4	10:30	..	1	9	2	..	3:00	..	6	4	..	9:20	8-20
Year	4	4	4	..	5:50	5	5	2	9:40	..	..	11	4	..	3:10	..	8	4	..	9:00	9-20

Table XII indicates the average time of occurrence of the lowest and highest temperature of the day for each month and for the year; the morning and the afternoon hours when the mean temperature of the day is most likely to occur; the frequency of occurrence of these phases at given hours; and the average number of hours between the occurrence of the highest and lowest temperatures of the day. The values are based on hourly observations for the ten-year period from 1893 to 1902. See also Fig. 12.

The January minimum may occur from 5 a. m. to 8 a. m., the normal time being 6.50 a. m. In May, June, and July the minimum occurs with great regularity at about 5 a. m., and in September and October at 6 a. m. There is more uniformity in the time of occurrence of the maximum temperature of the day; this does not vary greatly from the hour of 3 p. m. at any season of the year. The earliest occurrence of the maximum is in the month of November. The time interval between the

minimum and maximum of the day increases steadily from the winter months to the summer months. Beginning with eight hours and thirty minutes in January, the interval reaches a maximum in May when it amounts to ten hours and twenty minutes, then decreases regularly to eight hours in November. This difference in time is due mostly to variations in the time of occurrence of the minimum temperature.

Diurnal Variation as Affected by Clouds and Rain.

In considering the diurnal variation of temperature in the preceding paragraphs the character of the day does not enter into the problem. The average values given include all days for a period of ten years. The amplitude of variation of temperature is manifestly largely dependent upon the presence or absence of clouds. On a cloudy day the sun's rays are largely absorbed by the cloudmass and comparatively little of the sun's heat-rays reach the earth's surface directly. To discover to what extent the normal daily variation is affected by the character of the day the diurnal variation of temperature has been determined for selected days in each season. For this purpose the days were grouped as clear, cloudy, and rainy. Days were regarded as clear during which the percentage of sunshine exceeded 90 per cent of the possible amount for the day. They were considered cloudy when the sky was overcast the entire day. A day was considered rainy when rain fell for more than four hours, not necessarily consecutive. Each group included approximately 100 days, selected from all seasons of the year. A further restriction was imposed by excluding days with a moderate or a high wind, as it was desired to eliminate the effect of wind velocity upon the diurnal variation in this problem.

The results of the above classification are shown in Fig. 13, in which some interesting and instructive relations are revealed. The amplitude, or difference between the lowest and highest temperature of the day, is manifestly greatest on clear days, with a maximum in the spring months. Cloudiness reduces the daily range of temperature to less than one-half of that on a clear day. On a rainy day the difference between the maximum and minimum is reduced to 2° or 3°, equivalent to about one-fourth the range on a clear day in winter and to about one-sixth

the range in spring, summer, and autumn. The principal phases of the diurnal march of temperature do not materially change in the summer and autumn months. The minimum occurs approximately at sunrise and the maximum of the day in the early afternoon hours. There is a marked deviation, however, from the normal conditions on rainy days in autumn and winter. After attaining the maximum for the day it is

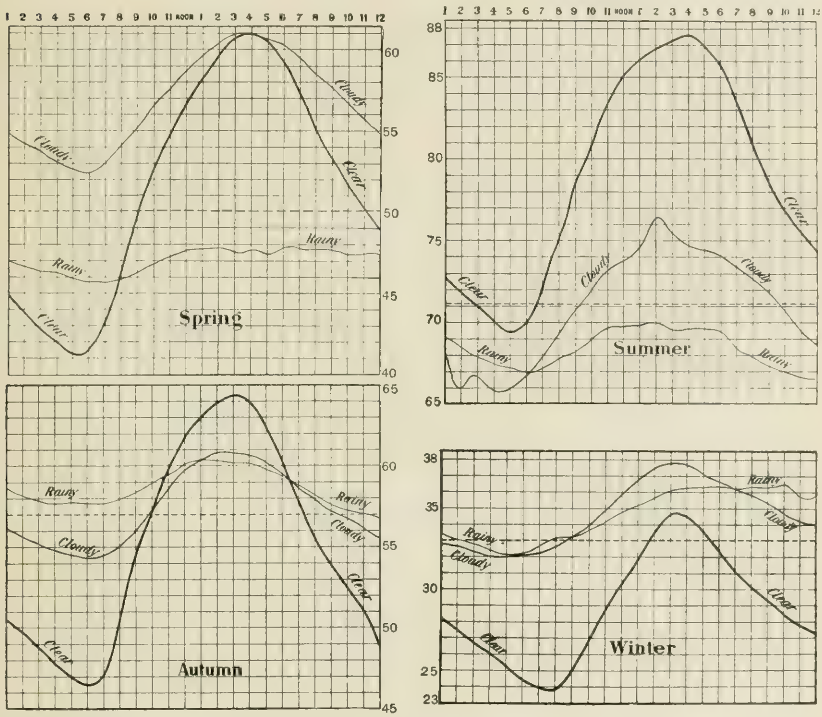


Fig. 13.—Effect of Cloudiness and Rain on the Hourly Variations of Temperature.

maintained until nearly midnight. One of the most interesting facts revealed in the diagrams is the relative position of the curves for clear, cloudy, and rainy days in the different seasons. In winter the clear day has a temperature decidedly below the normal for the season, while the cloudy and rainy days are well above the normal. In spring the clear day has about the normal temperature; the cloudy day is far above the normal; the rainy day is decidedly below the normal. In summer the clear

day is decidedly warmer than the average for the season; the cloudy day is about normal; the rainy day is much below the normal. In autumn the clear day is somewhat below the average temperature, the cloudy day is about normal, and the rainy day is well above the normal. These differences in temperature depending upon the extent of cloudiness and precipitation are in some cases very large. In spring the early morning temperatures may be 10° to 15° lower with a clear sky than with an overcast sky. In autumn there is quite as marked a difference between a clear and a rainy day in the early morning hours. In the summer months the midday temperatures may be reduced 10° to 12° by an over-

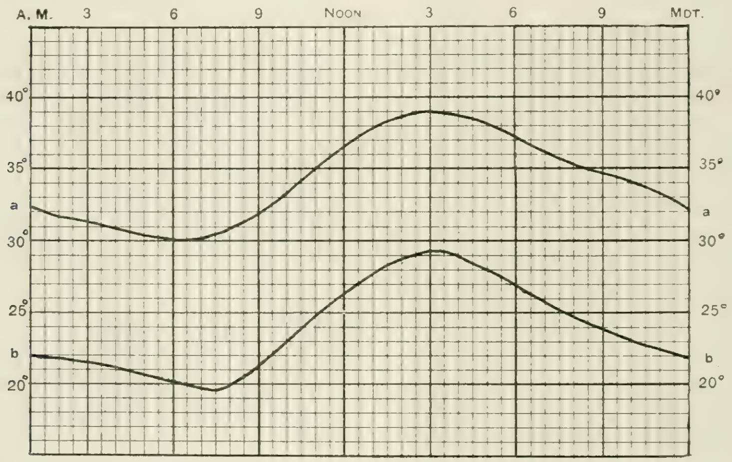


FIG. 14.—Effect of Snow-Covering on the Hourly Variations of Temperature.
(*a*) A normal winter day.
(*b*) Average of days with snow on the ground.

cast sky, and 15° to 20° during a rain. During the autumn an overcast sky will maintain the average temperature of the day 6° to 8° above that of a clear day.

MEAN HOURLY TEMPERATURE ON CLEAR, ON CLOUDY AND ON RAINY DAYS.

	Winter.	Spring.	Summer.	Autumn.
Normal Temperature	34.0°	53.2°	75.3°	57.7°
Clear days (Departures).........	−5.2°	−1.7°	+3.4°	−2.8°
Cloudy days "	+0.6°	+3.5°	−4.2°	−0.4°
Rainy days "	+0.5°	−6.2°	−7.0°	+0.9°

Effect of a Snow Covering.

To determine the effect of a snow covering upon the diurnal variation of temperature the average hourly temperature was calculated for all days within the period of ten years from 1893 to 1902 upon which the ground was covered with snow to a depth of half an inch or more. The values for the entire season are shown in the accompanying table and in Fig. 14 in comparison with the normal temperatures for the winter season. The two curves are identical in form and run parallel throughout their extent, but the days with snow on the ground were uniformly about 10° below the normal temperature for the winter months.

HOURLY TEMPERATURES ON DAYS WITH SNOW ON THE GROUND.

Hours: A. M.	1	2	3	4	5	6	7	8	9	10	11	Noon.	
Winter normal..	32.1	31.6	31.2	30.8	30.4	30.2	30.0	30.5	31.6	33.1	34.9	36.3	
With snow on ground	21.8	21.2	20.8	20.4	20.0	19.5	19.2	19.5	20.7	22.6	24.6	26.0	
Departure below normal	10.3	10.4	10.4	10.4	10.4	10.7	10.8	11.0	10.9	10.5	10.3	10.3	
Hours: P. M.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Mid-night.**	**Means.**
Winter normal..	37.5	38.4	38.8	38.6	37.7	36.7	35.8	35.2	34.3	33.8	33.2	32.7	34.0
With snow on ground	27.3	28.3	28.9	28.9	27.8	26.8	25.7	24.9	24.0	23.4	22.5	22.0	23.6
Departure below normal	10.2	10.1	9.9	9.7	9.9	9.9	10.1	10.3	10.3	10.4	10.7	10.7	10.4

The temperature is lowered during the night by the intenser radiation from a snow surface; it is prevented from rising during the day because much of the heat of the sun which would otherwise go to warm the atmosphere is spent in melting and vaporizing the snow. The air temperature is likewise reduced by the snow preventing the communication of heat from the ground by convection. As observations show that the difference between the normal hourly winter temperature and the hourly temperature over a snow-covered ground is practically constant throughout the day and night, the daily range is neither increased nor decreased by the presence of snow. The low average temperature of the winter of 1903-1904 was doubtless largely due to the exceptional duration of a snow cover. The depth of snow was not great, in the vicinity of Balti-

more, but a moderate snow covering persisted during a period of time nearly double the usual length. There is some compensation in the beneficial protection afforded by snow to winter wheat and to vegetation in general by preventing the penetration of frost into the ground.

The Effect of Wind Velocity on Temperature.

Another factor which largely affects the diurnal range of the thermometer is the movement of the atmosphere. It is well known that in a quiet atmosphere there may be a great difference in temperature at the earth's surface and a small distance above. In the night and early morning hours of winter the thermometer may register 5° or 10° lower near the ground than on the house tops; on a hot summer's day the difference at midday may be quite as large but reversed. In either case the lower layers of the quiet atmosphere tend to take on the temperature of the ground. Such differences are particularly common in the lower-lying portions of any locality. They do not occur in an active atmosphere; a breeze will quickly level any marked differences in the temperature of any neighboring strata of air by intermingling of the lower and higher layers resulting in an approximately uniform temperature. The effect of wind movement on the diurnal range of temperature may be clearly shown by classifying a large number of days according to total daily wind movement, days which in other respects have approximately similar conditions. The results of such a classification are graphically shown in Fig. 15. An equal number of clear or approximately clear days was selected in each of the months of January, March, July, and October. Those having a total daily wind movement of less than 100 miles per day were placed in one group; another group contained days with a total daily wind movement between 200 miles and 300 miles; still another group comprised winter and summer days with a wind movement exceeding 400 miles per day. The average hourly temperature was then determined for each group separately and a comparison made between the resulting temperatures. In each case the diurnal range of temperature is seen to be markedly lower with increase in wind movement. In the following tabular statement the total daily range for each condition mentioned above is given, while in the succeeding table the hourly

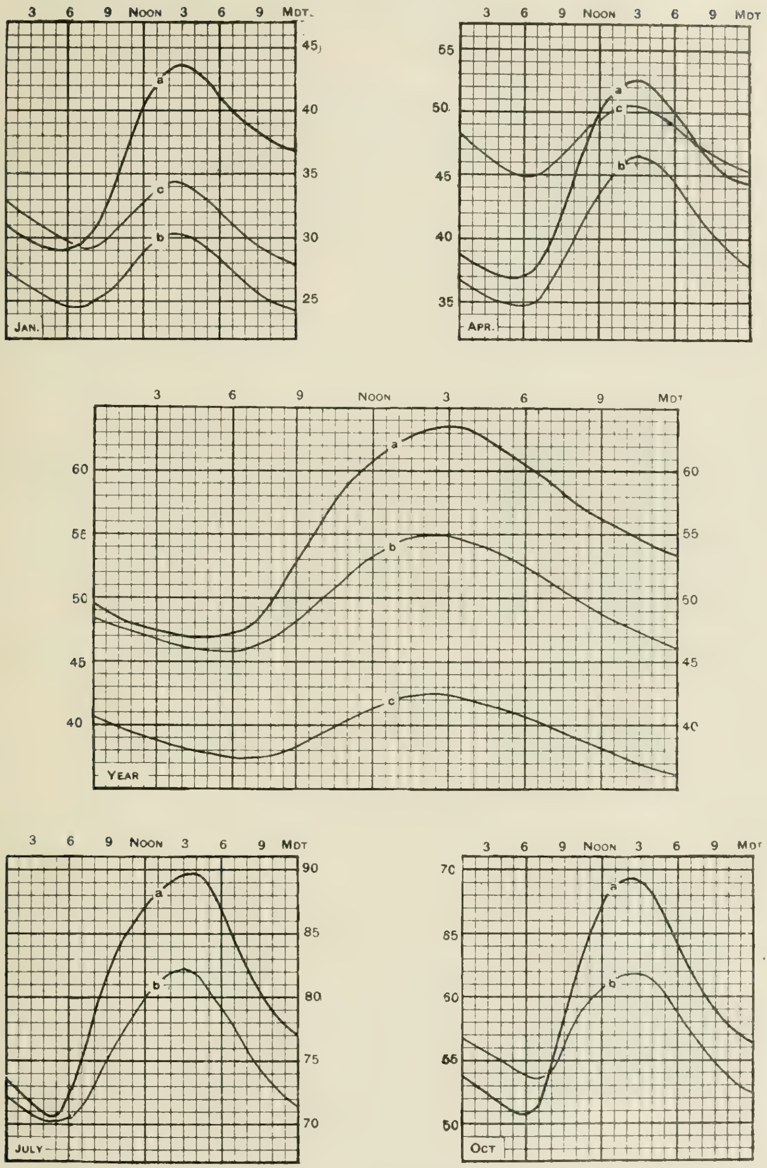


FIG. 15.—Effect of Wind Velocity on the Hourly Variations of Temperature.

(*a*) On days with a light wind.

(*b*) On days with a moderate wind.

(*c*) On days with a high wind.

changes are shown for the year, expressed in terms of departures from the normal temperatures for the year.

Range of Temperature on Calm and Windy Days.

Total daily wind movement.	Jan.	March.	July.	Oct.	Year.
Less than 100 miles......	14.6°	15.4°	19.5°	18.9°	16.8°
From 200 to 300 miles....	5.9°	12.0°	11.0°	8.2°	9.0°
Over 400 miles.........	Winter 5.2°		Summer 5.7°		5.4°

HOURLY TEMPERATURE ON CALM AND ON WINDY DAYS.

(Expressed in terms of departures from the normal temperature.)

Hours: A. M.	1	2	3	4	5	6	7	8	9	10	11	Noon.	
Normal Temperature..........	51.7°	51.1°	50.5°	49.9°	49.4°	49.4°	50.2°	51.8°	53.7°	55.6°	57.5°	59.0°	
50–100 Miles (Departures)......	− 2.6	− 2.7	− 2.6	− 2.6	− 2.6	− 2.6	− 2.6	− 1.9	− 1.0	+ 0.1	+ 1.0	+ 1.7	
200–300 Miles (Departures)......	− 3.6	− 3.5	− 3.4	− 3.3	− 3.2	− 3.5	− 4.6	− 5.0	− 5.4	− 5.7	− 6.4	− 6.2	
Over 400 Miles (Departures)..	−11.1	−11.2	−11.2	−11.2	−11.3	−11.9	−13.2	−14.5	−15.7	−16.6	−17.7	−18.1	
Hours: P. M.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Midnight.**	**Means.**
Normal Temperature.........	60.1°	61.0°	61.3°	61.1°	60.2°	59.0°	57.5°	56.3°	55.0°	54.1°	53.2°	52.5°	55.0°
50–100 Miles (Departures)......	+ 2.1	+ 2.1	+ 2.3	+ 2.2	+ 2.1	+ 1.6	+ 1.7	+ 1.2	+ 1.1	+ 1.1	+ 1.0	+ 1.1	+ 0.1
200–300 Miles (Departures)......	− 6.4	6.4	− 6.5	− 6.4	− 6.4	− 6.3	− 6.3	− 6.2	− 6.0	− 6.0	− 6.0	− 6.1	− 5.3
Over 400 Miles (Departures)..	−18.5	−18.7	−18.9	−19.1	−19.2	−18.6	−18.1	−17.5	−17.0	−16.7	−16.2	−16.1	−15.8

Reduction to the True Mean Temperature.

As it is often inconvenient or impossible to make daily observations of the temperature at the hours best suited to the purpose of securing an accurate average value, it is desirable to know the corrections to be applied to any selected combination of hours in order to arrive at a true average value for the day for a given locality. This can readily be done whenever hourly observations, or continuous records, have been maintained somewhere within a hundred miles or so of the locality, provided the physiographical conditions of the two localities do not differ widely from one another. In the following table the necessary corrections have been computed for the horizon of Baltimore for some of the

combinations of hours of observation employed at different times within the State of Maryland.

CORRECTIONS TO REDUCE OBSERVED TEMPERATURES TO THE TRUE DAILY MEAN.

Hours of Observation: — (75th Meridian Time.)	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
⅓ (7:37 a. + 4:37 p. + 11:37 p.)....	+0.2	+0.1	+0.1	+0.1	0	0	+0.2	+0.3	+0.3	+0.5	+0.5	+0.3	+0.2
⅓ (7:00 a. + 2:00 p. + 9:00 p.)....	−0.3	−0.3	−0.3	−0.3	−0.5	−0.7	−0.4	−0.5	−0.2	−0.2	−0.3	−0.3	−0.4
¼ (7:00 a. + 2:00 p. + 2(9:00 p.)....	−0.3	−0.4	−0.4	−0.4	−0.3	−0.4	−0.1	−0.3	0	0	−0.2	−0.3	−0.3
⅓ (7:00 a. + 3:00 p. + 11:00 p.)....	0	0	+0.1	+0.1	+0.2	0	+0.3	+0.3	+0.3	+0.4	+0.2	0	+0.1
⅓ 7:00 a. + 3:00 p. + 10:00 p.).....	−0.2	−0.2	−0.2	−0.2	−0.2	−0.3	−0.1	−0.1	+0.1	+0.1	−0.1	−0.2	−0.2
½ (10:00 a. + 10:00 p.)............	+0.5	+0.4	+0.4	−0.1	0	−0.2	−0.1	−0.2	+0.1	+0.2	+0.3	+0.7	+0.2
½ (Maximum + Minimum).....	−0.4	−0.3	−0.4	0	+0.1	+0.2	+0.1	0	−0.2	−0.4	−0.5	−0.5	−0.4
½ (8:00 a. + 8:00 p.)..............	+1.1	+1.2	+1.2	+0.8	+0.7	+0.5	+0.8	+1.3	+1.1	+1.6	+1.5	+1.3	+1.0
⅕ (7 a. + 11 a. + 3 p. + 7 p. + 11 p.)	−0.5	−0.6	−0.8	−1.1	−1.2	−1.3	−1.1	−1.2	−1.0	−0.8	−0.6	−0.6	−0.9

In a system of three hours of observation the combination 7 a.m., 3 p. m. and 11 p. m., gives a mean value very close to the 24-hourly mean, the annual average differing from the latter by only 0.1°, while the maximum departure is but + 0.4° during the month of widest divergence. During four months of the year, namely, January, February, June and December, no corrections need be applied. One of the best combinations of two hours is that of 10 a. m. and 10 p. m., which yields an average but 0.2° above the true annual mean. The maximum and minimum readings of self-registering thermometers require a correction of — 0.4° to the annual average. Considering the great convenience of one observation a day over two or more and the further advantage of showing the highest and lowest temperatures, this is the most desirable system to adopt. The United States Weather Bureau maintains an organization of about 3500 co-operating voluntary observers, all reporting daily maximum and minimum temperatures.

The Hourly Rate of Change.

While the temperature increases steadily from sunrise to about 3 p. m. and then steadily decreases to sunrise, the rate of warming and cooling

has its own period which differs from that of the temperature itself. The temperature rises most rapidly from 8 a. m. to 10 a. m., depending upon the season of the year, and falls most rapidly from 6 p. m. to 7 p. m. The hours of least change coincide with those in which the maximum and minimum temperatures of the day occur. In selecting a combination of hours for observation it is important to bear in mind this varying rate of change, and to avoid as far as practicable the hours of maximum rate. Consideration of this point is of no consequence when maximum and

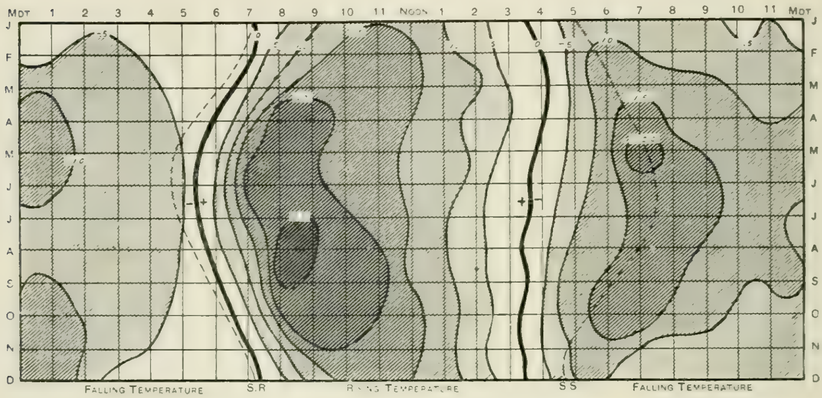


FIG. 16.—Hourly Rate of Change of Temperature.

Fig. 16 shows the extent of change in the temperature from hour to hour throughout the day and year. The values are based on hourly records during a period of ten years. The hours of the day are indicated by the upper horizontal line of figures, and the months of the year by the marginal letters. The areas without shading show the time of day when the change in temperature is least, the heavy black line within this area marking the time of change from falling to rising, or rising to falling temperature. The areas with darkest shading show the time of most rapid change. A falling temperature is designated by a minus sign, a rising by absence of sign, before the figure representing the amount of change in degrees and tenths. The dotted lines marked S.R. and S.S. show the time of sunrise and sunset. The time of most rapid rise in the temperature is between 8 a. m. and 9 a. m., the time of most rapid fall is between 7 p. m. and 8 p. m. See Table XIII and Fig. 17.

minimum thermometers are employed, or when a continuous record of the temperature is maintained. The approximate time at which the rate of change is greatest and least for each month and for the year is shown below in connection with the hours of maximum and minimum temperature of the day.

TIME OF DIURNAL MAXIMUM AND MINIMUM RATE OF WARMING AND COOLING.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Time of Max. temp. (p. m.).	3:00	3:30	4:00	3:30	3:30	3:00	3:00	3:00	3:00	3:00	3:00	3:00	3:00
" " Min. rate (p. m.)..	3:00	3:00	3:00	3:30	3:30	3:00	3:00	3:00	3:00	3.00	3:00	3:00	3:00
" " Min. temp. (a. m.).	7:00	7:00	6:00	6:00	5:00	5:00	5:00	5:00	6:00	6:00	7:00	7:00	6:00
" " Min. rate (a. m.)..	7:00	6:00	6:00	5:30	5:00	4:30	5:00	5:30	6:00	6:00	6:30	6:30	5:30
" " Max. rate (a. m.)..	10·00	10:00	10:00	9:00	9:00	8:30	8:30	8:00	9:00	9:00	9:00	10:30	9:30
" " Max. rate (p. m.)..	6:30	5:30	6:30	7:00	7:00	7:00	7:30	7:30	6:30	6:30	6:30	6:00	6:30

TABLE XIII.—MEAN HOURLY CHANGE OF TEMPERATURE.

(Expressed in degrees and tenths of a degree.)

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Midn't to 1 a. m...	— .4	— .3	— .8	—1.4	—1.3	—1.2	— .8	— .9	— .5	— .3	— .1	— .2	— .8
1- 2........	— .4	— .5	— .7	— .8	— .8	— .8	— .7	— .6	— .6	— .6	— .4	— .5	— .6
2- 3...	— .4	— .5	— .6	— .7	— .7	— .8	— .8	— .8	— .8	— .6	— .5	— .3	— .6
3- 4......	— .4	— .4	— .5	— .5	— .6	— .6	— .6	— .6	— .7	— .6	— .5	— .4	— .6
4- 5........	— .4	— .4	— .4	— .6	— .5	— .6	— .5	— .6	— .6	— .4	— .4	— .4	— .5
5- 6........	— .2	— .2	— .3	— .1	.4	.9	.3	.1	— .3	— .4	— .3	— .4	.0
6- 7	— .2	— .1	.2	1.0	1.6	2.1	1.8	1.6	.9	.3	— .1	— .1	.8
7- 8......	.3	.6	1.0	2.1	2.3	2.3	2.3	2.6	2.6	2.0	.9	.4	1.6
8- 9........	.9	1.3	1.7	2.2	2.1	2.3	2.5	2.4	2.3	2.4	2.0	1.2	1.9
9-10........	1.4	1.6	1.7	2.0	1.8	1.8	1.9	2.3	2.5	2.4	1.9	1.5	1.9
10-.1.	1.4	1.8	1.8	1.9	1.9	1.7	1.8	2.1	2.1	2.2	1.9	1.9	1.9
11-Noon....	1.3	1.5	1.7	1.5	1.3	1.2	1.5	1.2	1.6	1.7	1.6	1.5	1.5
Noon-1 p. m...	1.0	1.2	1.3	1.1	1.1	1.2	1.0	1.1	1.1	1.1	1.2	1.3	.9
1- 2........	.8	1.1	1.2	.8	1.0	.9	.6	.7	.8	.8	.6	.9	.9
2- 3.... ...	.4	.3	.5	.6	.2	.3	.2	.1	.3	.2	.2	.4	.2
3- 4........	— .2	.0	.1	.0	.0	— .1	— .1	— .3	— .1	— .4	— .6	— .5	— .2
4- 5........	— .8	— .7	— .8	— .6	— .5	— .9	—1.0	—1.0	—1.2	—1.2	— .8	—1.0	— .9
5- 6........	— .8	—1.2	—1.0	—1.1	—1.2	—1.3	—1.3	—1.1	—1.7	—1.6	—1.2	—1.0	—1.2
6- 7........	— .9	— .9	—1.4	—1.7	—2.0	—1.9	—1.7	—1.7	—1.8	—1.7	—1.1	— .9	—1.5
7- 8........	— .5	— .8	—1.1	—1.3	—1.8	—1.6	—1.8	—1.8	—1.4	—1.4	— .8	— .7	—1.2
8- 9	—1.0	— .8	—1.1	—1.3	—1.5	—1.5	—1.7	—1.4	—1.6	—1.2	— .9	— .8	—1.3
9-10.... ...	— .2	— .6	— .9	—1.1	—1.1	—1.3	—1.0	—1.2	—1.1	—1.0	— .7	— .6	— .9
10-11.......	— .7	— .6	— .8	— .9	—1.1	—1.1	—1.1	—1.2	— .7	— .9	— .8	— .6	— .9
11-Midn't...	— .3	— .5	— .8	—1.1	— .6	—1.0	— .8	—1.0	—1.1	— .8	— .7	— .7	— .7

Table XIII shows the average amount of change in temperature from hour to hour in each month and in the year. The minus sign preceding a number indicates a fall in temperature; numbers without a sign show a rise in temperature. For example, from midnight to one a. m., the temperature falls, on the average, four-tenths of a degree in the month of January, one and four-tenths in April, and eight-tenths, on the average, for the entire year. The results are also graphically shown for each month in the year in Fig. 16, and for the year, in Fig. 17. The values are based on hourly observations for a period of ten years.

In Table XIII, the average amount by which the temperature changes from hour to hour throughout the day is recorded for each month and

for the year. These values are derived from ten years of hourly observations from 1893 to the close of 1902. In Fig. 16, the values are graphically shown for each month of the year in terms of departures above and below a line separating the rising from the falling temperatures. In Fig. 17 the curve representing the average hourly rate of change in temperature for the year is drawn in connection with the average hourly pressure curve. As noted above in the paragraph on the diurnal variation of the barometer there is a close resemblance between these two curves, suggesting some causal connection between the diurnal warming and cooling of the atmosphere and pressure changes.

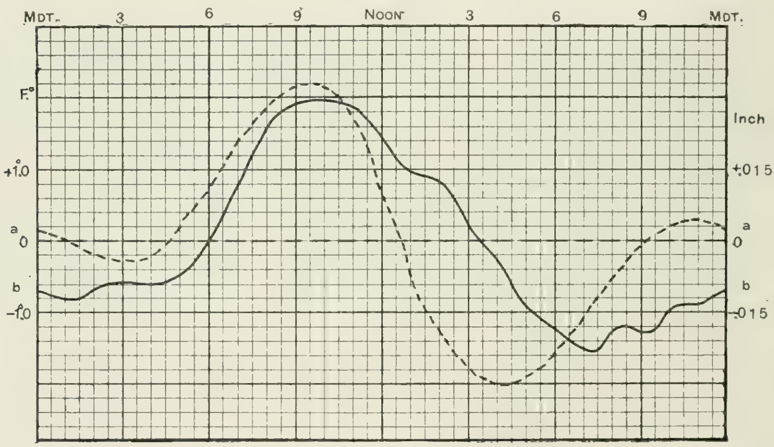


FIG. 17.—Curves Representing the Average Hourly Pressure (*a*), and the Hourly Rate of Change in Temperature (*b*), for the Year.

MEAN DAILY TEMPERATURE.

Just as the daily change in altitude of the sun causes a daily rise and fall in temperature, so the annual variations in altitude give rise to an annual rise and fall in temperature. In the diurnal period, the highest temperature is attained about three hours after the sun reaches the meridian; in the annual period the maximum temperature is reached from three to four weeks after the sun attains the greatest elevation. While the lowest temperature of the day occurs about sunrise, the minimum for the year lags four to five weeks behind the time of lowest seasonal altitude

of the sun. The steady advance and retreat of the sun in his annual course would probably cause a uniform increase in temperature from day to day from winter to summer, and a corresponding decrease to the winter months, if the character of the earth's surface were uniform. The distribution of land and water surfaces is doubtless responsible for the irregular character of the curve representing the annual changes of temperature when constructed from mean daily temperatures.

TABLE XIV.—MEAN DAILY TEMPERATURE.

(Corrected to hourly mean.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	33.5	33.9	38.2	47.0	59.3	70.2	75.5	76.6	72.4	62.5	51.5	36.3
2	34.3	31.5	38.0	49.2	60.5	69.0	75.7	76.4	71.8	61.6	52.4	38.3
3	32.2	33.9	38.7	48.8	58.9	71.2	78.1	76.6	72.7	62.2	50.1	38.5
4	33.2	33.8	37.8	48.4	59.5	71.4	78.7	76.6	72.0	63.0	47.7	39.0
5	33.2	30.9	36.8	48.7	61.2	71.2	77.5	76.7	72.4	60.9	48.5	37.9
6	33.0	32.7	39.0	49.8	60.9	71.6	77.5	77.0	73.6	60.7	49.0	38.3
7	34.4	34.3	40.2	49.8	60.7	70.4	77.7	76.8	71.8	59.0	48.8	39.3
8	33.7	35.3	39.5	50.6	61.7	72.1	77.7	77.0	71.4	59.4	49.6	38.6
9	33.0	34.7	40.3	50.2	64.9	72.6	77.9	77.4	70.6	59.0	49.9	38.7
10	32.2	34.5	43.1	50.2	66.2	72.3	77.9	77.5	70.3	59.0	49.3	37.8
11	31.6	36.1	41.4	50.6	65.8	72.6	77.7	76.8	68.6	58.7	47.7	40.0
12	34.0	36.7	42.8	51.2	64.5	72.4	77.6	76.8	69.7	57.4	47.1	39.9
13	33.2	36.1	41.8	52.4	62.7	72.4	78.5	76.2	69.6	58.0	46.3	39.7
14	34.8	35.3	40.6	55.2	61.9	73.3	78.2	75.6	67.6	58.1	44.9	38.3
15	33.1	35.9	39.0	53.2	63.8	73.8	78.9	75.6	67.1	56.9	45.3	36.9
16	34.6	35.7	39.9	52.8	64.0	72.8	79.6	75.4	69.0	57.8	46.2	36.2
17	33.8	36.5	39.2	52.7	63.4	73.9	78.9	75.0	68.8	57.4	45.7	36.3
18	33.2	37.5	39.8	53.4	63.9	73.8	79.1	75.6	67.7	57.2	46.3	36.3
19	33.9	37.3	43.2	55.2	65.5	74.6	77.3	75.4	69.3	56.2	44.3	35.9
20	34.2	36.3	41.4	55.4	66.5	75.6	77.3	75.4	66.8	54.7	42.0	33.9
21	36.0	37.5	41.2	55.9	66.4	75.6	77.5	75.8	64.6	54.6	41.3	35.7
22	35.5	38.1	42.2	55.6	66.1	75.2	76.7	75.2	64.8	54.3	42.8	37.3
23	35.1	37.1	41.2	57.2	65.2	75.1	77.6	74.3	65.4	55.0	43.7	37.8
24	32.2	35.3	41.0	57.6	65.7	76.1	76.8	74.6	65.2	54.1	41.7	36.5
25	32.4	37.4	42.0	56.4	67.1	75.9	77.3	74.4	64.8	53.1	41.5	35.5
26	32.5	37.7	42.5	57.5	67.5	77.6	78.7	74.0	65.4	53.4	41.6	34.3
27	33.8	36.0	44.0	57.8	67.3	76.2	78.2	72.8	64.0	53.8	41.9	34.0
28	34.8	35.9	45.0	58.0	68.6	76.6	77.1	72.1	64.1	52.3	40.8	32.9
29	33.6	36.6	43.4	57.4	67.3	76.2	77.4	72.6	64.0	52.6	38.1	33.7
30	33.0		44.5	59.7	68.8	75.6	77.5	73.4	62.9	52.0	36.2	34.1
31	34.3		46.2		70.3		76.9	73.2		50.6		33.8

Table XIV shows the mean temperature for each day of the year as derived from the daily maximum and minimum temperatures for 30 years, from 1871 to 1900. To the average daily values derived from these observations, corrections have been applied to reduce them to the true mean based on 24 hourly observations. The altitude of the thermometers varied from 40 to 60 feet above the ground.

In Table XIV the average temperature for each day of the year is shown, based upon the daily maximum and minimum temperature for a period of thirty years. The corrections which were found necessary in

the preceding paragraphs, in order to reduce these values to the true daily mean based on 24-hourly observations, have been applied in this table. In Plates III and IV the daily mean temperatures for the same period (1871-1900) of thirty years, are shown graphically in curves B. The irregular serrated appearance of these curves is very marked. The advance and retreat of the seasons is accomplished by a succession of waves of rising and falling temperature, of unequal period, but averaging about three to four days. These changes accompany the areas of high and low atmospheric pressure which pass in continual succession from west to east within the temperate zones of the northern and southern hemispheres, and which have become familiar to us in the daily weather charts now isssued by nearly all national governments.

A study of the curves representing the daily temperatures for the year, shows a greater variability in the winter months than in the summer months. This is more readily recognized in the curves of extreme temperatures (Plate IV, curves A and C), than in those representing the average temperature for a long period (curve B). In the past thirty years the temperature has been lowest, on the average in Baltimore, on the 5th of February (30.9°). The day having the highest average temperature of the year is the 16th of July (79.6°). Hence the temperature rises during 161 days and falls during a period of 204 days. From April 20th to October 23rd the temperature remains above the average for the year; from October 23rd to April 20th it is below. The temperature rises most rapidly in March and falls most rapidly in November.

As stated above, the temperature of the air at the earth's surface lags behind the temperature of direct solar radiation nearly a month, the latter attaining a maximum value on June 22nd, the former about July 17th, at Baltimore. This lagging effect is particularly noticeable in the temperature of late summer and the autumn. On the 22nd of March and of September the direct rays of the sun which fall upon Baltimore are presumably of approximately equal intensity, as the sun is at these times directly over the equator. The temperature of the air, however, screened from the direct rays of the sun, is 65° on September 22nd, while it is only 42° on the 22nd of March. This marked difference between the

temperatures of corresponding days of the ascending and descending branches of the annual curve holds good throughout the year.

TABLE XV.—MEAN DAILY CHANGE OF TEMPERATURE.

(Expressed in degrees and tenths of a degree.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
0- 1	—0.4	—0.5	1.7	0.4	—0.5	—0.2	0.0	—0.2	—0.6	—0.2	1.0	0.1
1- 2	0.8	—2.4	—0.2	2.2	1.2	—0.2	0.2	—0.2	—0.6	—0.9	0.9	2.0
2- 3	—2.1	2.4	0.7	—0.4	—1.6	2.2	2.4	0.2	0.9	0.6	—2.3	0.2
3- 4	1.0	—0.1	—0.9	—0.4	0.6	0.2	0.6	0.0	—0.7	0.8	—2.4	0.5
4- 5	0.0	—2.9	—1.0	0.3	1.7	—0.2	—1.2	0.1	0.4	—2.1	0.8	—1.1
5- 6	—0.2	1.8	2.2	1.1	—0.3	0.4	0.0	0.3	1.2	0.2	0.5	0.4
6- 7	1.4	1.6	1.2	0.0	—0.2	—1.2	0.2	—0.2	—1.8	—1.7	—0.2	1.0
7- 8	—0.7	1.0	—0.7	0.8	1.0	1.7	0.0	0.2	—0.4	0.4	0.8	—0.7
8- 9	—0.7	—0.6	0.8	—0.4	3.2	0.5	0.2	0.4	—0.8	—0.4	0.3	0.1
9-10	—0.8	—0.2	2.8	0.0	1.3	—0.3	0.0	0.1	—0.3	0.0	—0.6	—0.9
10-11	—0.6	1.6	—1.7	0.4	—0.4	0.3	—0.2	—0.7	—1.7	—0.3	—1.6	2.2
11-12	2.4	0.6	1.4	0.6	—1.3	—0.2	—0.1	0.0	1.1	—1.3	—0.6	—0.1
12-13	—0.8	—0.6	—1.0	1.2	—1.8	0.0	0.9	—0.6	—0.1	0.6	—0.8	—0.2
13-14	1.6	—0.8	—1.2	2.8	—0.8	0.9	—0.3	—0.6	—2.0	0.1	—1.4	—1.4
14-15	—1.7	0.6	—1.6	—2.0	1.9	0.5	0.7	0.0	—0.5	—1.2	0.4	—1.4
15-16	1.5	—0.2	0.9	—0.4	0.2	—1.0	0.7	—0.2	1.8	0.9	0.9	—0.7
16-17	—0.8	0.8	—0.7	—0.1	0.6	1.1	—0.7	—0.4	—0.2	—0.4	—0.5	0.1
17-18	—0.6	0.1	0.6	0.7	0.5	—0.1	0.2	0.6	—1.1	—0.2	0.6	0.0
18-19	0.7	—0.2	3.4	1.8	1.6	0.8	—1.8	—0.2	1.6	—1.0	—2.0	—0.4
19-20	0.3	—0.1	—1.8	0.2	1.0	1.0	0.0	0.0	—2.5	—1.5	—2.3	—2.0
20-21	1.8	1.2	—0.2	0.5	—0.1	0.0	0.2	0.4	—2.2	—0.1	—0.7	1.8
21-22	—0.5	0.6	1.0	—0.3	—0.3	—0.4	—0.8	—0.6	0.2	—0.3	1.5	1.6
22-23	—0.4	—1.0	—1.0	1.6	—0.9	—0.1	0.9	—0.9	0.6	0.7	0.9	0.5
23-24	—2.9	—1.8	—0.2	0.4	0.5	1.0	—0.8	0.3	—0.2	—0.9	—2.0	—1.3
24-25	0.2	2.1	1.0	—1.2	1.4	—0.2	0.5	—0.2	—0.4	—1.0	—0.2	—1.0
25-26	0.1	0.3	0.5	1.1	0.4	1.7	1.4	—0.4	0.6	0.3	0.1	—1.2
26-27	1.3	—1.7	1.5	0.3	—0.2	—1.4	—0.5	—1.2	—1.4	0.4	0.3	—0.3
27-28	1.0	—0.1	1.0	0.2	1.3	0.4	—1.1	—0.7	0.1	—1.5	—1.1	—1.1
28-29	—1.2	0.7	—1.6	—0.6	—1.3	—0.4	0.3	0.5	—0.1	0.3	—2.7	0.8
29-30	—0.6		1.1	2.3	1.5	—0.6	0.1	0.8	—1.1	—0.6	—1.9	0.4
30-31	1.3		1.7		1.5		—0.6	—0.2		—1.4		—0.3
Average ±	1.0	1.0	1.2	0.8	1.0	0.6	0.6	0.4	0.9	0.7	1.0	0.8

Table XV shows the change in the mean daily temperature from day to day throughout the year. The minus sign indicates a fall in temperature while absence of the sign indicates a rise. For example: The 1st of January is 0.4° colder, on the average, than the day preceding; the 9th of May is 3.2° warmer than the 8th of May, etc. The same results are shown in curves B of Plates III and IV. These values are based on daily average temperatures for a period of thirty years.

Average Inter-Diurnal Changes of Temperature.

The changes in the average temperature from day to day are indicated with greater accuracy in Table XV than in the curves on Plates III and IV. The amount of rise or fall in temperature from day to day throughout the year is given to tenths of a degree. The average variability is

approximately 0.8°, and varies from 1.0° or 1.2° in the winter months to 0.5° or 0.6° in the summer months when the changes are considered without reference to sign. The month of greatest variability is March, while July is the month of least variability. The annual march of temperature shows some interesting periods of marked rise and fall, periods of three or more days during which there is a conspicuous departure from the path representing a steady progressive change. Such periods

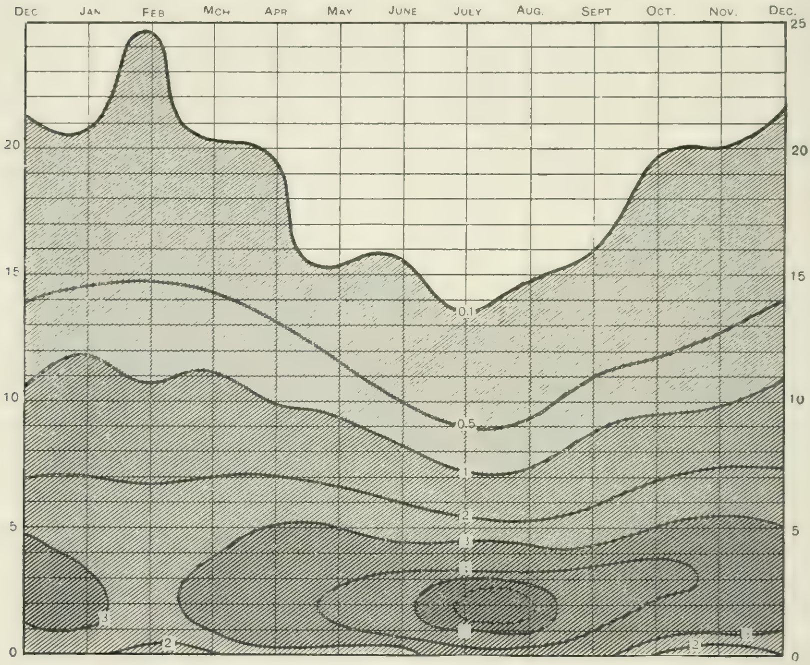
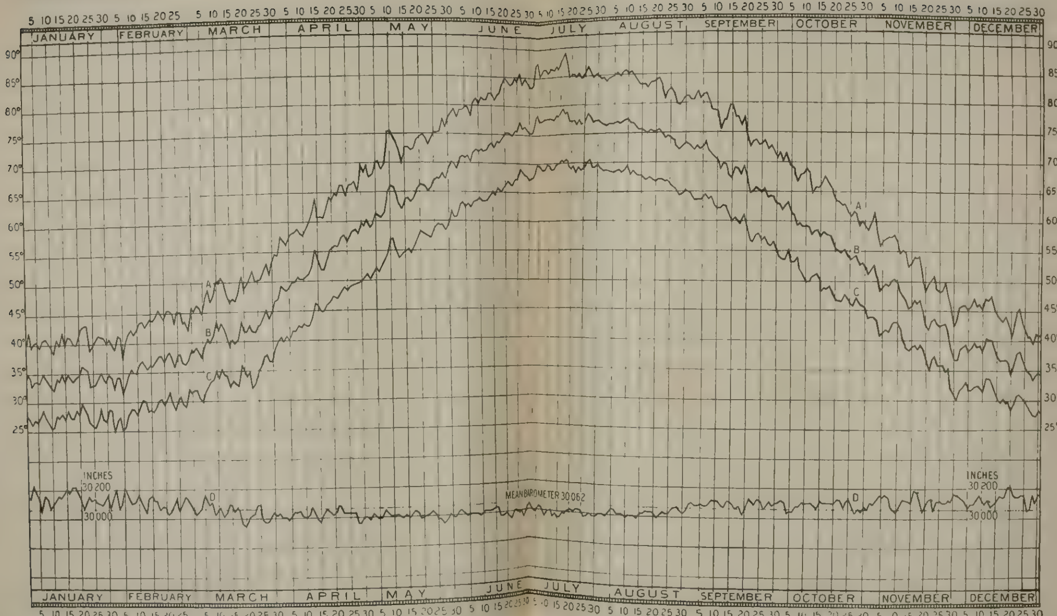


FIG. 18.—Inter-diurnal Temperature Changes.

Fig. 18 shows the average monthly frequency of changes of stated amounts in the mean temperature of the day from day to day. The marginal figures indicate the degree of change, and the heavy curved lines the frequency of stated changes. For example, a change of 2° in the mean daily temperature occurs on the average 3.2 times in January, 2.6 times in February, 4.7 times in June, and 5.5 times in August, etc. Increase in the intensity of the shading represents increase in the frequency of occurrence. See also Table XVII.

have received a great deal of attention from European climatologists and there is an abundant literature of a popular as well as scientific character grouped about these special days. Throughout central and southern Europe there is a popular impression that injurious frosts are likely to occur



DAILY MARCH OF TEMPERATURE AND PRESSURE.

BASED UPON DAILY OBSERVATIONS FOR 30 YEARS.

A. Average daily maximum temperature. B. Daily mean temperature. C. Average daily minimum temperature. D. Daily mean barometric pressure.

in the early part of May, and their coming is awaited with anxiety by the agricultural classes, especially in France and northern Germany. May 11, 12 and 13, are the days of most probable occurrence and these days have been variously designated as the "Three Ice Saints," the "Three Ice Men," etc., by the husbandmen. Similar regressions in temperature have been noted at other seasons of the year and carefully investigated but the spring drop occurring at a critical period in crop growth has received by far the largest share of attention.

In a study of the tendency to the formation of frosts from the 10th to the 13th of May in Europe, Dr. Assmann has shown that the fall in temperature is first shown in Scandinavia, spreads in a southerly and then in a southwest direction over Central Europe. The maximum departure is attained on the 10th. Receding eastward, at first slowly and then more rapidly, it reaches the Russian provinces of the Baltic on the 13th. Daily weather charts constructed by van Bebber show a progressive departure of pressure which readily accounts for a period of northerly winds and clear skies and abnormally low temperature, first over northern Europe, then southward over central Europe and France.

Careful study of the daily temperature at Baltimore does not disclose a tendency toward a decided fall in temperature on these days. On the contrary, there is a distinct rise from the 9th to the 12th in place of the European fall (see curves A. B. and C, Plate III). A similar plus departure in temperatures at this time is disclosed in the daily temperature curves of other localities, namely, Washington, Norfolk, Nashville, Columbus, Ohio. The geographical extent of this marked departure has not yet been carefully investigated, but it is not confined to the localities named. A probable explanation of this phenomenon may be found in a periodic recurrence at this time of an area of high barometric pressure over the South Atlantic states, or an extension westward of the permanent area of high pressure over the North Atlantic in latitude of about 30° in conjunction with the development of a barometric depression in the Mississippi Valley. Such a pressure distribution invariably causes a rise in temperature above the average for the time of year in the central states and the Middle Atlantic states.

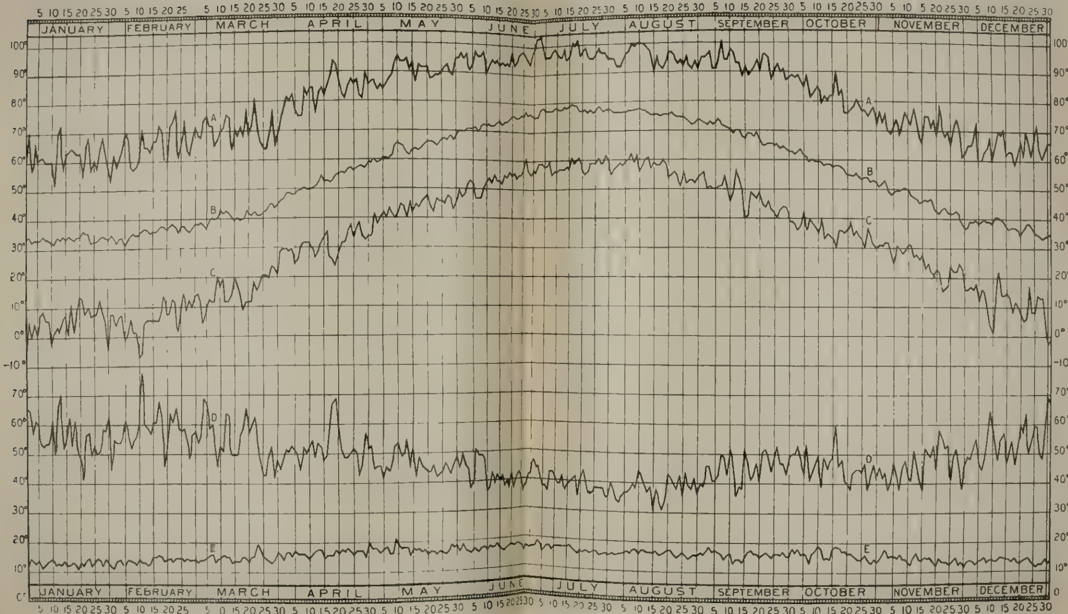
A similar period of marked rise occurs at Baltimore about March 7 to 12 and again April 12 and 13. About June 20, and again about July 20, there is apparently a tendency for the temperature to fall below the normal for two or three days. These marked departures from the steady and uniform seasonal advance or retreat of temperature conditions do not always occur upon the same days, year after year, but the fact that

TABLE XVI.—MEAN DAILY RANGE OF TEMPERATURE.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	12.0	11.3	14.4	14.7	18.0	19.0	15.9	16.0	15.9	17.8	15.9	13.3
2	15.0	13.9	13.3	17.1	18.4	17.1	16.1	15.3	16.9	16.7	17.8	14.1
3	13.5	14.5	14.4	17.2	17.5	16.6	18.9	15.9	18.6	18.2	14.8	13.7
4	13.1	13.2	14.5	15.4	16.9	16.1	17.9	16.2	17.1	15.9	15.3	12.6
5	13.9	12.5	14.9	17.4	18.0	17.4	15.7	16.6	17.7	16.4	15.5	13.4
6	11.7	14.4	15.9	16.5	19.1	16.9	16.4	16.9	16.9	16.0	15.2	13.8
7	12.0	13.9	16.5	16.7	16.3	16.0	17.5	16.2	16.5	12.9	16.0	15.0
8	13.6	13.6	13.6	16.5	16.3	17.4	17.5	17.3	14.7	16.5	14.6	13.2
9	13.8	12.7	14.4	16.1	21.4	17.9	16.1	17.3	16.1	17.6	14.7	14.1
10	14.3	14.5	14.8	15.2	18.8	16.7	17.3	15.8	16.6	19.1	13.6	14.2
11	12.7	13.3	15.8	16.3	18.0	18.1	17.5	17.7	13.2	18.4	12.7	13.4
12	13.0	13.5	15.5	17.5	18.3	17.7	17.6	16.3	14.6	14.3	15.1	13.3
13	12.4	12.5	15.6	17.9	18.3	17.6	17.3	15.9	14.6	14.9	16.3	14.9
14	14.1	13.1	13.6	18.2	15.5	18.3	17.4	15.5	13.7	14.6	14.0	14.4
15	12.4	15.6	14.2	15.2	17.8	17.2	17.5	15.6	14.8	18.1	13.9	14.2
16	12.6	15.6	13.8	16.1	17.4	16.7	18.0	16.2	16.8	19.1	14.8	14.0
17	13.7	15.9	14.1	15.8	17.8	16.2	16.9	15.7	17.7	18.5	14.4	12.9
18	12.9	15.4	15.7	16.0	17.0	17.2	16.7	16.2	16.6	17.2	14.9	14.4
19	11.2	14.1	14.9	17.9	17.3	18.7	15.5	16.6	16.6	17.3	13.5	13.0
20	13.4	14.6	13.6	16.3	16.2	19.2	16.4	17.3	15.4	16.6	11.8	12.3
21	12.7	15.1	15.7	18.2	17.2	17.3	15.8	17.3	15.9	16.7	14.3	13.6
22	14.4	13.7	15.3	17.5	16.9	17.3	16.6	16.1	17.2	16.2	13.4	13.9
23	15.2	14.9	19.9	18.5	15.8	17.8	16.2	14.8	16.1	15.1	13.5	14.6
24	12.3	15.1	17.3	17.5	16.9	17.8	16.0	15.3	15.2	14.6	12.8	13.1
25	13.5	15.2	15.5	15.9	16.5	17.4	16.7	16.7	16.3	14.6	12.4	12.0
26	14.8	14.2	14.6	17.4	15.9	17.0	16.7	16.2	16.6	15.9	13.6	11.6
27	14.4	14.8	14.1	17.3	16.3	15.2	15.0	14.5	16.1	14.2	15.1	12.6
28	12.2	14.7	13.5	17.5	18.8	17.1	15.7	15.4	16.8	13.0	12.2	12.1
29	14.5	9.6	14.5	15.7	17.9	16.7	16.2	15.9	15.5	14.3	13.3	13.9
30	13.5		16.8	20.2	18.4	16.3	15.4	15.9	15.6	13.7	11.4	12.4
31	11.8		15.9		16.7		15.5	16.3		14.7		13.6

Table XVI shows the average difference between the daily maximum and daily minimum temperatures for each day of the year, based on observations covering a period of 30 years.

they persist in a curve representing average conditions for a long series of years (over thirty years in the Baltimore series) would seem to point to a decided tendency toward the formation of a given system of pressure distribution upon these days. This subject of the periodic recurrence of similar weather types is a matter worthy of more attention than has yet been given to it in this country.



DAILY MARCH OF TEMPERATURE.

BASED UPON DAILY OBSERVATIONS FOR 30 YEARS.

A. Daily maximum temperature. B. Daily mean temperature. C. Daily minimum temperature. D. Extreme range of temperature E. Average daily range of temperature.

Average Daily Range.

The average maximum and minimum temperatures for each day of the year for a period of thirty years are shown graphically in curves A and C on Plate III. These curves show the characteristics already described in considering the *mean* daily temperatures, which was to be expected as the latter were derived from the daily maximum and minimum. The average daily range of temperature, or the average difference between the highest and lowest readings for each day, is shown in Table XVI. The daily range is also shown on Plate III by the difference in value of corresponding points in curves A and C and directly in curve E on Plate IV. During the winter months the range is least; it increases in the spring months, reaching a maximum in May and June, then decreases steadily to a minimum in January. As the daily range is largely dependent upon the amount of cloudiness and atmospheric movement, as shown in preceding paragraphs, a considerable variation in the range from year to year in the same month may be expected. In January, for instance, with a range of 13.2° as an average for thirty-two years, it has varied from 11.2° in 1891 to 17.0° in 1876. The March range has varied from 11.8° in 1891 to 22.0° in 1873. The smallest average range for any month occurred in November 1884, namely 10°; the greatest average was that of March, 1873, with 22.0°. When the daily range is averaged up for an entire year the variability is reduced to comparatively narrow limits. The annual average was smallest in the year 1882 (14.1°) and greatest in 1900 (16.9°). The ten-year averages have varied only between the limits 15.2° and 15.9°.

AVERAGE DAILY RANGE OF TEMPERATURE.

Period.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1871–1880........	13.8	14.2	15.9	16.1	17.6	16.7	16.3	14.8	15.7	16.8	14.0	13.6	15.5
1881–1890.......	13.5	14.4	14.6	17.1	16.6	17.0	16.2	15.7	15.1	15.0	13.5	13.3	15.2
1891–1900........	12.5	13.8	15.0	17.2	18.0	18.0	17.3	17.3	17.3	16.7	14.6	13.4	15.9
1871–1902........	13.2	14.1	15.3	16.7	17.4	17.4	16.7	16.0	16.1	16.3	14.0	13.4	15.6

Diurnal Variability of Temperature.

A climatic factor of the highest importance, especially to those who are not in the best of health, is the variability of temperature conditions from

day to day. The magnitude of the diurnal change may be represented in various ways: either by comparing the extremes of temperature of one day with those of the following, or the average daily temperatures, or readings

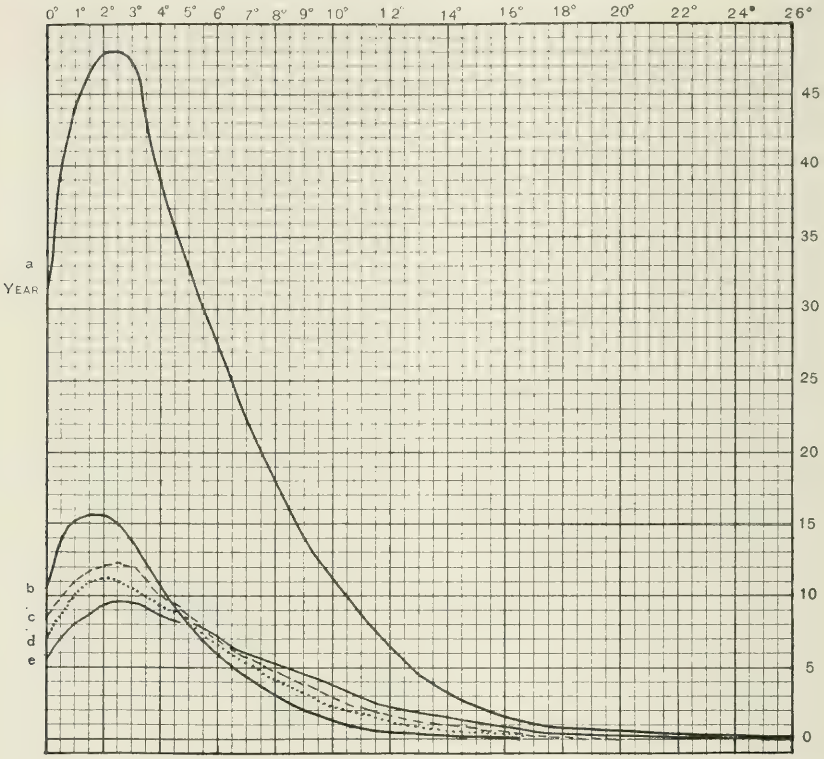


Fig. 19.—Total Seasonal and Annual Frequency of Stated Diurnal Changes of Temperature.

(a) Total Annual frequency.
(b) " Summer "
(c) " Autumn "
(d) Total Spring frequency.
(e) " Winter "

Fig. 19 shows the total number of stated changes in the mean daily temperature during each season and during the year. The upper horizontal line of figures indicates the degree of change, and the marginal figures to the right of the diagram show the frequency of stated changes. See also Table XVII.

made at the same hour of the day. The frequency of changes of a given amount will depend somewhat upon the method chosen for determining the daily change. We have seen above that the normal change in temper-

ature from day to day varies from 0.5° or 0.6° in the summer months to 1.0° or 1.2° in the winter months. But this average change for a long series of years is of less significance than the frequency of changes of a given amount. Large, and especially sudden, changes in temperature within short periods have never been considered particularly desirable from any point of view. Such changes may have advantages, but the uncomfortable, if not actually harmful effects, of rapid changes are sure to outweigh these. As a general rule proximity to the ocean will insure an equable temperature, free from sudden and large changes. Especially

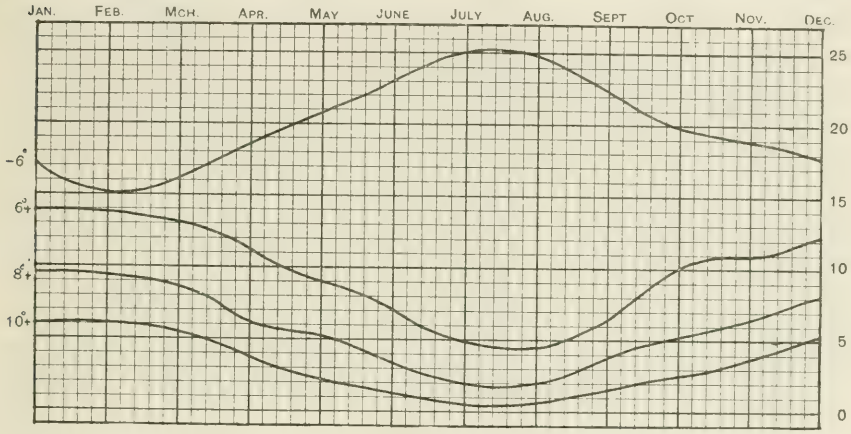


FIG. 20.—Diurnal Changes of Temperature of less than 6°, 6° +, 8° + and 10° + each month.

Fig. 20 shows the frequency of changes of 0° to 5°, of 6° and above, 8° and above, and of 10° and above, in the mean temperature of the day for each month of the year. The degree of change is indicated by the curved lines marked −6°, 6° +, 8° +, and 10° + respectively, while the frequency of the stated changes is shown by the marginal figures to the right of the diagram. For example, a rise or fall of 5° or less in the mean temperature of the day occurs on the average 17 times in January, 21 times in May, and 25 times in July, etc.; a rise or fall of 10° or more in the *mean* daily temperature occurs 6 times in January, 2 times in May, etc. See Table XVII.

is this true on small islands, or along the western coasts of the continents where ocean winds prevail. The diurnal variability increases rapidly as the interior portions of the continental areas are approached.

The changes in the daily *average* temperature at Baltimore, covering a period of thirty years, have been computed and arranged according to frequency and degree of change. These diurnal changes have also been

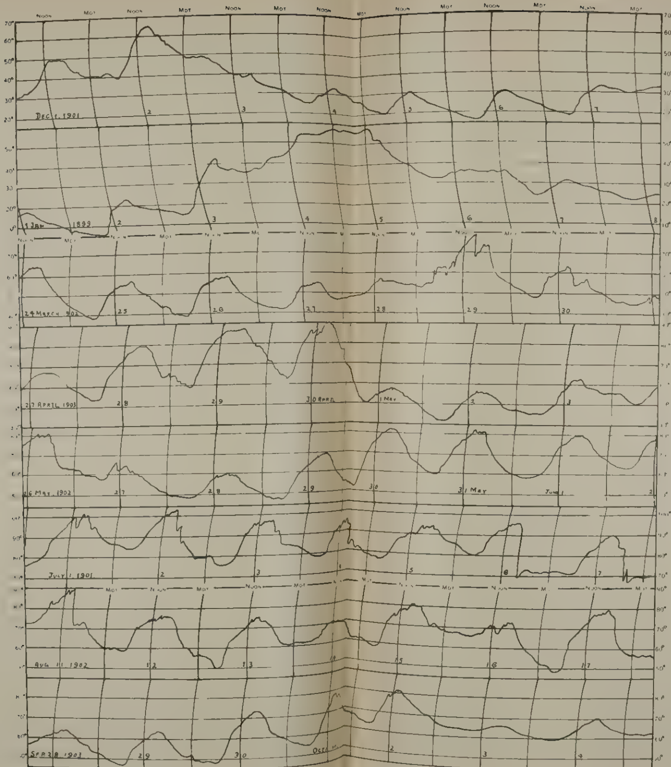
grouped according to months, seasons, and the year, in the table which follows and presented graphically in Figs. 18, 19, 20 and 21. In the summer months changes of one, two, and three degrees largely predominate, from which there is a rapid decrease in frequency of larger changes. In the winter months changes of one, two, and three degrees are still dominant, but the decrease in frequency as the changes increase is much more gradual.

TABLE XVII.—FREQUENCY OF STATED DIURNAL CHANGES OF TEMPERATURE.

Degrees.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Spring.	Summer.	Autumn.	Winter.	Year.
0°	2.0	1.9	1.7	2.5	2.5	2.9	3.5	3.7	3.6	1.7	1.9	1.8	6.7	10.2	8.3	5.7	30.8
1	3.0	2.4	3.1	3.2	3.9	4.4	5.5	5.4	4.4	3.6	3.1	3.1	10.2	15.3	11.1	8.5	45.0
2	3.2	2.6	3.6	3.4	4.2	4.7	5.6	5.5	4.3	3.8	3.6	3.4	11.1	15.7	11.7	9.3	47.8
3	3.2	2.7	3.3	3.4	3.9	4.2	5.0	4.9	4.2	4.2	3.9	3.5	10.6	14.0	12.3	9.4	46.3
4	2.7	2.7	2.6	3.2	3.3	3.2	3.2	3.3	2.9	3.5	3.6	3.0	9.1	9.6	10.0	8.4	37.1
5	2.6	2.7	2.6	3.3	3.0	2.7	2.6	2.5	2.6	3.2	3.3	3.0	8.9	7.8	9.0	8.3	34.0
6	2.2	2.3	2.2	2.6	2.3	2.0	1.8	1.5	1.9	2.2	2.4	2.5	7.0	5.3	6.5	6.9	25.7
7	2.1	2.0	2.0	2.2	1.9	1.7	1.3	1.1	1.8	2.1	2.0	2.1	6.1	4.2	5.8	6.2	22.2
8	1.8	1.7	1.6	1.4	1.4	1.2	0.7	0.7	1.2	1.5	1.4	1.5	4.5	2.6	4.2	5.0	16.3
9	1.7	1.5	1.8	1.2	1.2	0.9	0.5	0.5	1.0	1.3	1.3	1.3	4.1	1.9	3.5	4.6	14.1
10	1.3	1.1	1.6	0.8	0.9	0.5	0.3	0.3	0.6	0.7	0.9	1.0	3.3	1.1	2.5	3.5	10.2
11	1.1	0.9	1.2	0.7	0.7	0.3	0.2	0.1	0.6	0.6	0.8	1.0	2.6	0.7	2.0	3.0	8 3
12	1.0	0.6	0.7	0.5	0.4	0.2	0.1	0.1	0.3	0.4	0.6	0.7	1.7	0.4	1.3	2.3	5.6
13	0.8	0.6	0.6	0.5	0.2	0.1	0.1	0.1	0.3	0.3	0.4	0.6	1.3	0.3	1.0	2.0	4.7
14	0.6	0.4	0.5	0.3	0.1	..	..	0.1	0.1	0.2	0.2	0.5	1.0	0.1	0.5	1.5	3.0
15	0.3	0.5	0.4	0.2	0.1	0.1	..	0.1	0.1	0.2	0.2	0.4	0.7	0.2	0.5	1.2	2.6
16	0.2	0.3	0.3	0.1	..	0.1	..	..	..	0.1	0.1	0.3	0.4	0.1	0.3	0.8	1.6
17	0.1	0.3	0.2	0.1	..	..	..	..	..	0.1	0.1	0.2	0.3	..	0.3	0.6	1.3
18	0.1	0.2	0.1	0.1	..	..	..	..	..	0.1	0.1	0.2	0.2	..	0.2	0.5	0.8
19	0.1	0.1	0.1	0.1	..	..	..	..	..	0.1	0.1	0.1	0.2	..	0.2	0.4	0.8
20	0.1	0.1	..	0.1	..	..	..	..	..	0.1	0.1	0.1	0.1	..	0.1	0.3	0.6
21	0.1	0.1	..	..	..	..	..	..	..	..	..	0.1	..	..	..	0.2	0.3
22	..	0.1	..	..	..	..	..	..	..	..	..	..	..	..	..	0.1	0.2
23	..	0.1	..	..	..	..	..	..	..	..	..	..	..	..	..	0.1	0.2
24	..	0.1	..	..	..	..	..	..	..	..	..	..	0.1	..	..	0.1	0.2
25	..	0.1	..	..	..	..	..	..	..	..	..	..	..	..	..	0.1	0.1
26	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0.1	0.1

The first column indicates the degree of change from day to day in the average daily temperature. The figures in the remaining columns show the average monthly, seasonal and annual frequency of occurrence of indicated changes, based upon observations during 30 years, from 1871 to 1900.

The larger daily changes decrease in frequency on the approach of the summer months. A change of 10° in the average temperature of two consecutive days has occurred about 35 times in 30 years during each winter month and 9 times in each of the months of July and August.



TYPICAL THERMOGRAMS

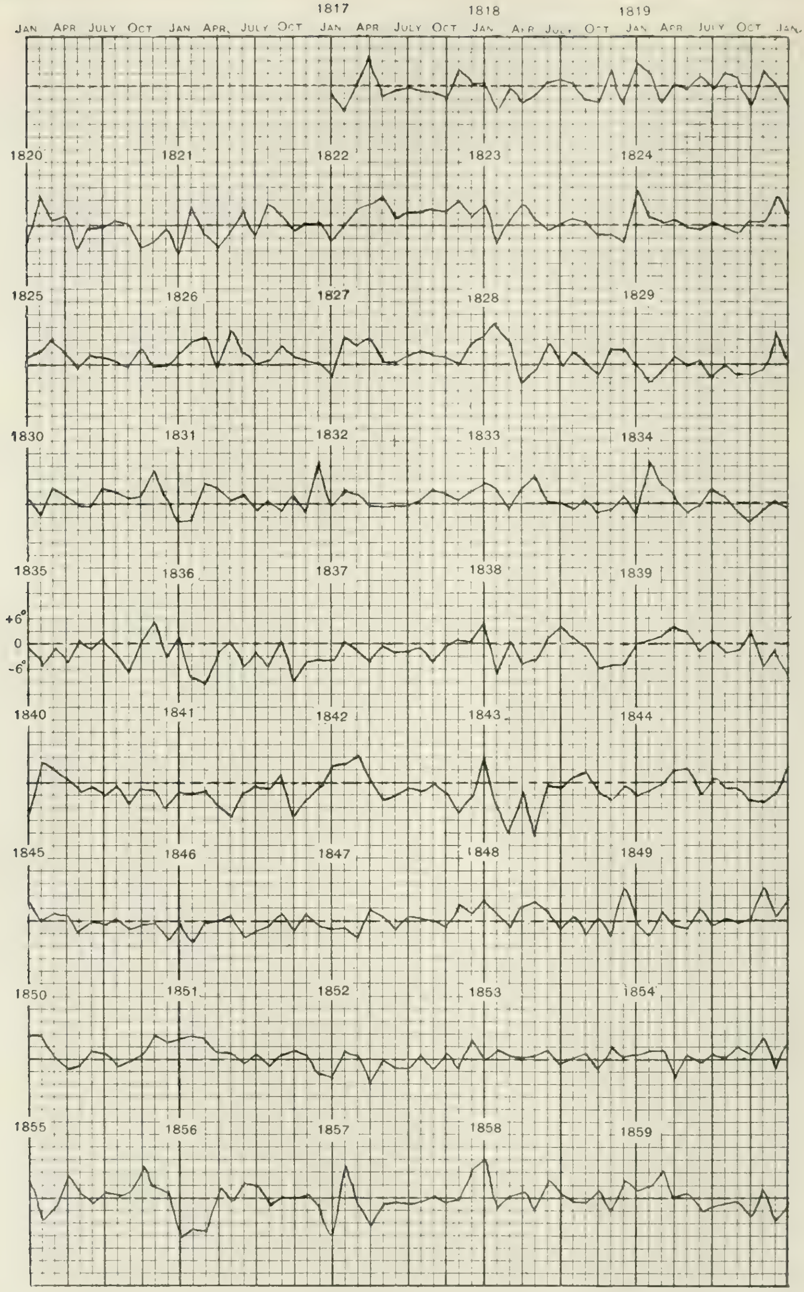
The details of these changes are shown in the table above and in Figs. 18, 19, 20 and 21.

These figures and the diagrams reveal the interesting fact that the average departure and the most frequent departure are not identical, or that the arithmetical mean of all departures for any given month is not the most probable value. In the winter months the *average* departure is about 1°, in the summer months it is about 0.6°. The most probable departure is in all months larger than the average departure, as is clearly brought out in the following comparison of the average change from day to day and the most probable change.

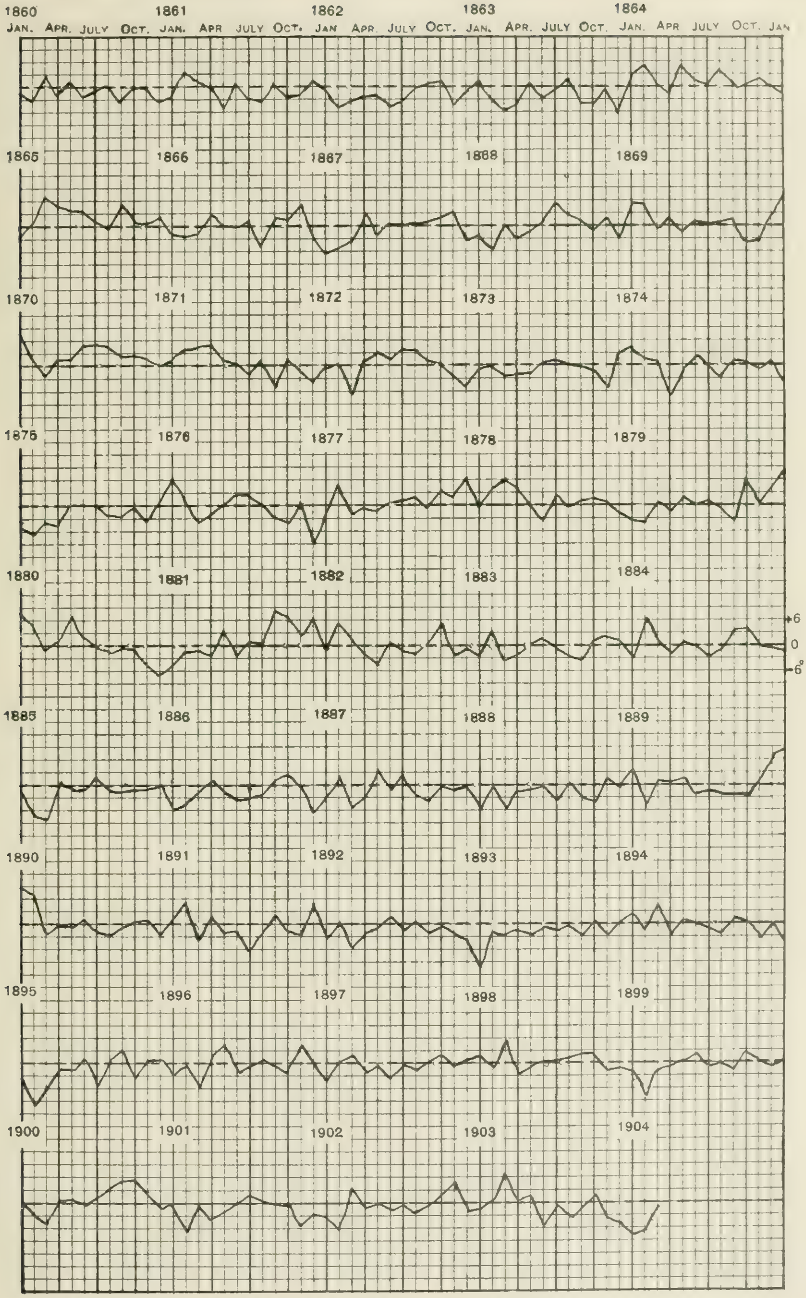
DIURNAL VARIABILITY.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Average change..±	1.0°	1.0°	1.2°	0.8°	1.0°	0.6°	0.6°	0.4°	0.9°	0.7°	1.0°	0.8°	0.8°
Most probable change........±	3°	4°	2°	3°	2°	2°	2°	2°	1°	3°	3°	3°	2°

The true measure of diurnal variability is the change in the *average* temperature from day to day. It is more convenient, however, to express this change by means of the difference between the highest or the lowest temperature of successive days, or between the temperature at any given hour, as 8 a. m. of one day to 8 a. m. of the following day, or from 8 p. m. to 8 p. m. The results will differ somewhat according to the method adopted. Assuming as correct the variability as measured by means of the daily *average* temperature, the variability based on differences of the minimum temperature from day to day will give too many changes under 6°, while those based on the 8 a. m., 8 p. m. and the maximum temperatures yield too few small changes, the departure from the true frequency being in the order named. On the other hand when we consider the larger changes of 6°, 8°, or 10° and above, the minimum temperature yields too many. Take as an illustration the frequency of changes of 10° and over. During the course of a year of average temperature conditions there are 41 diurnal changes of 10° or more, basing the count on the daily minimum, 59 on the 8 a. m., 58 on the 8 p. m., and 83 on the maximum temperatures. That is to say, the variability computed from differences in the maximum temperature from day to day may show more than double the



DEPARTURES OF MEAN MONTHLY TEMPERATURE FROM NORMAL FOR 87 YEARS.


1860
1861
1862
1863
1864
JAN. APR. JULY OCT. JAN. APR JULY OCT. JAN APR. JULY OCT. JAN. APR. JULY OCT. JAN. APR JULY OCT. JAN
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1896
1897
1898
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1900
1901
1902
1903
1904

true frequency of the larger changes of 10° and above, while the smaller changes are below the true frequency; hence changes in the daily maximum temperature are not a safe guide to the diurnal variability in the geographical horizon of Baltimore. In all cases the changes based upon observation of the maximum temperature from day to day differ most widely from those based on changes of the average daily temperature. In Fig. 21 and in the following table these results are shown graphically for changes under 6°, for 6°+, 8°+, 10°+ and 20°+, when the diurnal

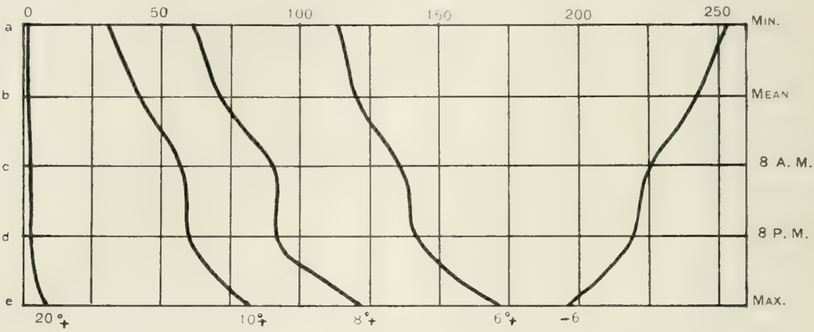


FIG. 21.—Diurnal Changes of Temperature of −6°, 6°+, 8°+, 10°+, 20°+.

Fig. 21 shows the frequency of stated changes in the temperature from day to day when based on the minimum temperature of two successive days, on the mean temperature, on the 8 a. m., on the 8 p. m., and on the maximum temperature, respectively. See also Fig. 20, and Table XVII. The frequency is indicated by the line of figures above the diagram, the degree of change, by the line of figures below the diagram.

variability is based on observations of the maximum, the minimum, the 8 a. m. and 8 p. m. readings and on the true daily mean. Diurnal changes were computed for a period of 30 years from the daily *average* temperature, and for a period of 10 years from the maximum, minimum, the 8 a. m., and the 8 p. m. observations.

FREQUENCY OF DIURNAL TEMPERATURE CHANGES OF STATED AMOUNTS.

(Expressed in terms of departures from the frequency based on changes in the daily mean temperature.)

Temperature changes.	Minimum.	Mean.	8 a. m.	8 p. m.	Maximum.
	Departure.		Departure.	Departure.	Departure.
Below 6°	+ 11	241	− 16	− 21	− 46
6° +	− 5	119	+ 19	+ 21	+ 51
8° +	− 10	71	+ 21	+ 20	+ 48
10° +	− 9	41	− 18	+ 18	+ 42
20° +	−0.4	1.7	+2.7	+2.3	+6.6

The smaller changes, under 6°, increase in frequency very rapidly from February to July, then decrease at a similar rate to February. Changes of 6° and over occur most frequently in the months of December, January, February and March; the decrease is then uniform until a minimum frequency is reached in August; then there is a more rapid increase to

TABLE XVIII.—FIVE-DAY MEANS OF TEMPERATURE.

(For five-day periods ending on given days.)

January.		February.		March.		April.		May.		June.	
5th	33.3	4th	33.5	1st	37.0	5th	48.4	5th	59.9	4th	70.4
10	33.3	9	33.6	6	38.1	10	50.1	10	62.9	9	71.6
15	33.3	14	35.7	11	40.9	15	52.5	15	63.7	14	72.6
20	33.9	19	36.6	16	40.8	20	53.9	20	64.7	19	73.8
25	34.2	24	36.9	21	41.0	25	56.5	25	66.1	24	75.5
30	33.5	....	....	26	41.8	30	58.1	30	67.9	29	76.5
....	....	....	....	31	44.6	....	...	....	....	....	....
July.		**August.**		**September.**		**October.**		**November.**		**December.**	
4th	76.7	3rd	76.8	2nd	72.7	2nd	63.0	1st	51.8	1st	38.7
9	77.7	8	76.8	7	72.5	7	61.2	6	49.5	6	38.4
14	78.0	13	76.9	12	70.1	12	58.7	11	49.1	11	38.9
19	78.8	18	75.4	17	68.4	17	57.6	16	46.0	16	38.2
24	77.2	23	75.2	22	66.6	22	55.4	21	43.9	21	35.6
29	77.7	28	73.6	27	65.0	27	53.9	26	42.3	26	36.3
....	...	....	....	....	....	....	....	....	....	31	33.7

TEN-DAY MEANS OF TEMPERATURE.

(For ten-day periods ending on given days. Derived from above table of five-day means.)

January.		February.		March.		April.		May.		June.	
10th	33.3	9th	33.5	1st	37.0	10th	49.3	10th	61.4	9th	71.0
20	33.6	19	36.2	11	39.5	20	53.2	20	64.2	19	73.2
30	33.9	....	....	21	40.9	30	57.3	30	67.0	29	76.0
....	....	....	....	31	43.2	....	....	....	....	....	....
July.		**August.**		**September.**		**October.**		**November.**		**December.**	
9th	77.2	8th	76.8	7th	72.6	7th	62.1	6th	50.7	6th	38.5
19	78.4	18	76.2	17	69.3	17	58.2	16	47.5	16	38.5
29	77.5	28	74.4	27	65.8	27	54.6	26	43.1	26	36.0
....	....	....	....	..	....	....	....	....	....	Jan. 5	33.5

Table XVIII shows the mean temperature for each successive period of five days beginning with January 1st, and also for each successive period of ten days. The 5-day and 10-day means were computed from the normal daily temperatures for the 30-year period 1871-1900, after reducing the latter to the true daily temperature based on hourly observations.

December. A change of 20° in the average temperature of two successive days has occurred at Baltimore about 50 times in the 30 years from 1871 to 1900. Of these occurrences 15 were recorded in February, 10 in January, 8 in December, 5 in March, 5 in November, 2 in each of the

months of April, May, and October, none in the months of June, July, August and September. The most frequent change and hence the most probable, is a change of 2° in the spring and summer and 3° in the autumn and winter months.

The Probable Error of the Mean Daily Temperatures.

No law has yet been discovered governing the departures from the normal temperature of a year, month, or day. Departures above and below the normal for a long series of observations agree very closely in their distribution with chance occurrences. Hence the formula applicable to the latter has been employed in the determination of the probable error of average temperatures for a given period.

The equation used for finding the probable error of the daily, monthly, and annual means of temperature for Baltimore is a form suggested by Fechner * and is as follows:

$$E = v \frac{1.1955}{\sqrt{2n-1}}$$

in which E is the probable error, v the average departure from the normal temperature (in degrees Centigrade) not regarding the sign of the departure, and n the number of occurrences, in this case the number of years of observation. The value of the factor $\frac{1.1955}{\sqrt{2n-1}}$ is as follows for the stated periods of observation:

20	30	40	50	60	70	80	90	100 yrs.
0.191	0.156	0.134	0.120	0.110	0.102	0.095	0.089	0.085

In order to determine the probable error of the daily mean temperature at Baltimore for the 30-year period, from 1871-1900, the above formula was applied to a representative day in each season, namely, for the 15th day of January, April, July and October. In winter (represented by January 15), the average departure v of the mean daily temperature from the normal is 7°, in spring (April 15), 5°, in summer (July 15), 4°, in the autumn (October 15), 6°. In individual cases these departures vary greatly. On January 15, 1871, the mean daily temperature was 62°,

*See: Hann's Lehrbuch der Meteorologie. Leipzig, 1901, p. 107.

or 28° above the normal value; on January 15, 1893, the mean temperature of the day was 22° below the normal. Thus the 15th day of January shows a range in the average temperature of the day of 50°. The extremes on April 15th were 17° above and 11° below, a range of 28°; on July 15th 6° above and 12° below the average, a range of 18°; on October 15th the extreme departures were plus 15° and — 19°, a range of 34°. These figures strikingly illustrate the variability of temperature conditions within short periods at Baltimore.

THE FREQUENCY AND AVERAGE VALUE OF DEPARTURES FROM THE NORMAL DAILY TEMPERATURE.

January 15th.			April 15th.			July 15th.			October 15th.		
Departures.			Departures.			Departures.			Departures.		
Frequency.	Sums.	Average.	Frequency.	Sums.	Average.	Frequency.	Sums.	Average.	Frequency.	Sums.	Average.
+18 —15	+116.6° —116.5°	+6.5° —7.8°	+13 —20	+84.9° —84.0°	+6.5° —4.2°	+20 —13	+61.0° —60.2°	+3.0° —4.6°	+17 —16	+106.6° —105.2°	+6.3° —6.6°
33	233.1°	7.1°	33	168.9°	5.1°	33	121.2°	3.7°	33	211.8°	6.4°

Entering the values of the average departure v in the formula we obtain as the probable error of the mean temperature of a typical winter, spring, summer, and autumn day the following values:

January	April	July	October	Average Seasonal
1.1°	0.8°	0.6°	0.9°	0.8°

These figures represent the probable error of a daily mean temperature in the respective seasons for a series of observations at or near Baltimore covering a period of 30 years. The daily mean temperature will not be increased or decreased by an amount greater than these values by extending the series of observations.

Mean Monthly, Seasonal, and Annual Temperatures.

There is an excellent series of local temperature observations extending, with very few interruptions, from 1817 to date. For the series from 1817 to 1824 we are indebted to Captain Lewis Brantz, who kept a careful

record of the weather, in what was in his time West Baltimore, and presented his published results to the Maryland Academy of Sciences, of which he was a member. His observations were made at five stated hours of the day, at sunrise, 8 a. m., 2 p. m., sunset, and 10 p. m., and comprised the elements of pressure, temperature, wind-direction and force, clouds, and rainfall. In 1831 systematic observations of the principal climatic elements were made at 7 a. m., 3 p. m., and 9 p. m. at Fort McHenry, under the auspices of the U. S. Army. This series was maintained to the year 1892 with the exception of two or three years just preceding and during the Civil War. From 1871 to the present time a first order station of the U. S. Weather Bureau has been maintained at Baltimore.

To complete the record since 1817 it has been necessary to interpolate observations made at neighboring localities, applying, however, the proper corrections. This could readily be done as the different records overlapped. The break in the record from 1825 to 1830 was filled in by reducing Washington, D. C., observations to the Fort McHenry series; for the years 1859 to 1863 the excellent record maintained for 20 years at Shellman's Hills, about 20 miles due west from Baltimore, was utilized. A year's record by Captain Brantz in 1836 afforded a means of reducing his earlier observations to the Fort McHenry series. From 1871 to 1892 the Fort McHenry and the U. S. Weather Bureau records overlapped. All of these observations were ultimately reduced to the U. S. Weather Bureau series by applying the necessary corrections and were thus converted into a comparable and continuous record of great interest and value in the discussion of the climatic conditions of Baltimore City.

The monthly, seasonal, and annual means are presented in Table XIX. The departures from the normal values are shown in graphic form in Plates VI and VII. The table and diagrams afford excellent material for the study of the changes in temperature conditions experienced by Baltimoreans during the preceding century and incidentally the results throw light upon the assertion of the "oldest inhabitant" that our winters are growing milder, an assertion which has been persistently repeated since the earliest settlers arrived on our shores.

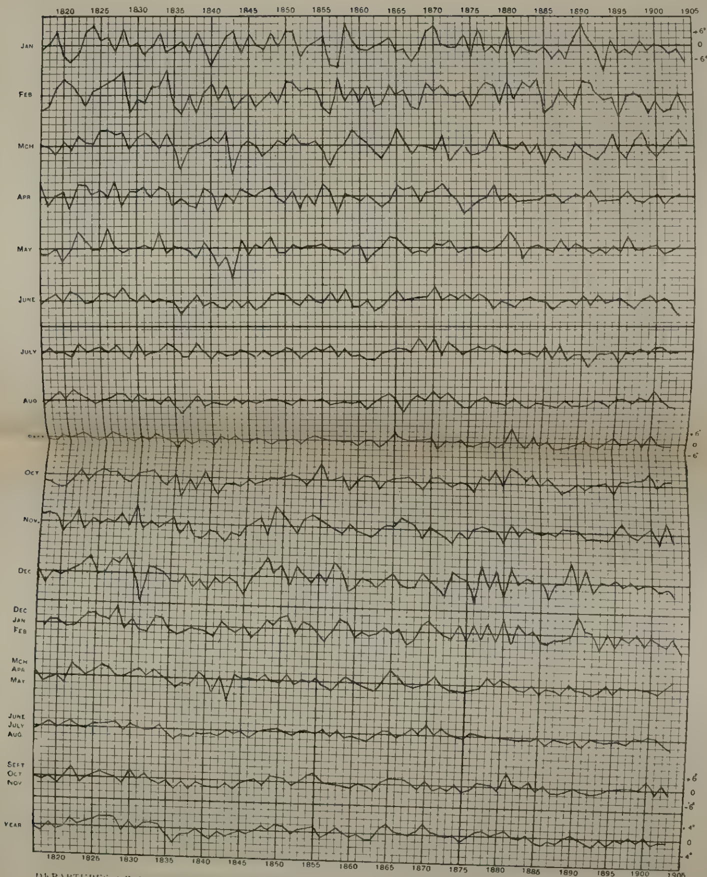
TABLE XIX.—MEAN TEMPERATURES AT BALTIMORE FOR 88 YEARS, 1817-1904.

Years.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Winter	Spring	Summer	Autumn	Seasons
1817	33.2	30.1	43.4	61.9	62.0	72.2	77.9	74.8	67.3	53.8	50.2	38.2	55.4	....	55.8	75.0	57.1	1817
1818	35.6	30.9	42.9	50.8	61.7	74.5	79.5	76.8	65.6	53.3	50.6	33.8	54.6	34.9	51.8	76.9	56.5	1817-8
1819	40.7	39.0	39.7	54.5	63.4	75.9	77.7	79.8	71.0	51.5	50.2	37.9	56.7	37.8	52.5	77.8	57.6	1818-9
1820	30.4	42.9	44.6	56.4	59.1	72.4	77.7	77.2	69.0	51.6	42.5	36.7	55.0	37.1	53.4	75.8	54.4	1819-20
1821	28.5	40.2	41.2	49.0	62.8	77.0	75.6	81.0	71.3	55.6	46.7	38.5	55.5	35.1	51.0	77.9	57.9	1820-1
1822	31.6	36.1	47.2	59.5	70.7	75.6	81.0	79.5	72.7	59.7	52.5	39.7	58.8	35.4	59.1	78.7	61.6	1821-2
1823	39.7	31.9	44.4	59.1	66.4	72.6	78.0	77.5	68.8	54.2	44.2	41.0	56.4	37.1	56.6	76.0	55.7	1822-3
1824	43.4	37.6	43.9	55.5	63.7	72.7	79.1	75.0	67.1	58.1	48.0	44.5	57.3	40.7	54.4	75.6	57.7	1823-4
1825	37.6	39.1	49.3	56.7	63.8	76.1	79.7	76.8	68.4	60.3	46.5	37.5	57.6	40.4	56.6	77.5	58.4	1824-5
1826	37.9	41.3	49.4	53.7	72.2	76.2	77.9	77.2	73.2	58.8	47.7	37.7	58.5	38.9	58.4	77.1	59.9	1825-6
1827	32.4	42.6	47.8	60.3	65.0	74.1	80.3	79.4	71.1	58.5	46.8	43.0	58.4	37.6	57.7	77.9	58.8	1826-7
1828	41.6	45.4	48.6	50.3	62.6	78.3	77.9	79.1	69.2	54.7	50.4	41.6	58.2	43.3	53.8	78.4	58.1	1827-8
1829	34.7	29.1	42.1	56.7	63.7	74.5	74.9	76.0	66.1	54.1	45.5	45.6	55.2	35.1	54.2	75.1	55.2	1828-9
1830	36.0	33.7	46.8	56.6	64.0	73.2	81.5	79.0	70.2	58.8	54.4	38.7	57.6	38.4	55.8	77.9	61.1	1829-30
1831	31.2	32.6	48.4	57.7	65.0	75.9	76.6	76.9	67.4	59.4	44.7	27.0	55.1	34.2	57.0	76.5	57.2	1830-1
1832	34.3	39.3	45.6	53.9	63.5	72.9	77.6	76.7	71.9	59.4	47.8	40.6	56.9	33.5	54.3	75.7	59.7	1831-2
1833	39.6	39.2	41.9	57.8	70.8	73.8	78.2	75.1	69.6	54.3	45.3	40.1	57.1	39.8	56.8	75.7	56.4	1832-3
1834	32.2	46.3	48.3	56.5	61.8	73.1	81.5	78.3	67.1	52.6	45.6	38.1	56.7	39.5	55.5	77.6	55.1	1833-4
1835	34.3	30.9	42.1	50.2	64.7	72.3	76.6	73.5	62.1	58.0	49.4	34.9	54.0	34.4	52.3	74.1	56.5	1834-5
1836	36.3	27.9	33.9	52.7	64.1	67.9	75.9	71.0	68.8	47.8	42.6	34.2	51.8	33.0	50.2	71.6	53.1	1835-6
1837	31.3	35.9	41.9	50.3	63.0	71.0	75.8	74.8	64.8	55.9	47.7	37.9	54.1	33.8	51.7	73.9	56.1	1836-7
1838	39.8	28.6	43.7	49.6	60.0	75.6	81.7	78.4	67.9	50.9	41.7	32.7	54.1	35.4	51.1	78.6	53.5	1837-8
1839	34.9	36.5	44.4	57.6	66.9	71.1	78.2	73.9	67.4	59.7	41.2	35.9	55.6	34.7	56.3	74.4	56.1	1838-9
1840	26.7	40.5	46.4	55.4	62.2	72.3	74.9	75.5	63.8	55.3	44.7	31.5	53.9	34.4	54.7	74.2	54.6	1839-40
1841	32.9	33.6	41.5	48.6	56.4	70.7	77.5	75.1	70.9	48.9	43.1	36.7	52.9	32.7	48.8	74.4	54.3	1840-1
1842	38.9	39.9	49.1	55.4	60.3	70.1	76.5	74.4	68.4	54.0	39.9	34.3	55.0	38.5	54.9	73.7	54.1	1841-2
1843	40.9	29.9	31.2	51.5	51.7	73.7	76.8	77.4	71.5	54.0	43.0	36.8	53.9	35.0	44.8	76.0	56.2	1842-3
1844	31.7	33.9	43.0	57.1	67.2	70.4	78.5	75.1	66.9	52.5	42.1	34.8	54.4	34.1	55.8	74.7	53.8	1843-4
1845	39.3	35.9	45.2	55.8	61.3	72.9	77.2	76.4	67.1	55.9	46.4	30.1	55.2	36.7	54.1	75.5	56.5	1844-5
1846	34.8	31.4	43.1	54.2	65.5	69.2	75.4	75.2	70.3	53.9	48.3	36.4	54.7	32.1	54.3	73.3	57.5	1845-6
1847	33.2	34.3	39.1	56.9	64.9	71.1	78.7	76.3	68.6	55.4	50.2	39.5	55.6	34.6	53.6	75.4	58.1	1846-7
1848	40.0	38.0	41.8	58.1	68.6	76.0	76.4	77.2	65.5	57.2	43.2	45.5	57.2	39.2	56.2	76.5	55.3	1847-8
1849	34.4	32.7	45.5	53.2	61.9	76.3	77.3	76.5	68.2	56.7	54.6	38.7	56.2	37.5	53.5	76.7	59.8	1848-9
1850	40.7	41.6	43.9	51.8	61.9	75.8	79.7	75.0	68.2	57.8	52.4	42.0	57.5	40.3	52.5	76.8	59.5	1849-50
1851	39.8	41.3	48.1	55.9	65.5	72.5	79.4	74.6	69.7	58.5	47.6	33.9	57.2	41.0	56.5	75.5	58.6	1850-1
1852	30.5	37.7	44.1	49.2	63.9	71.2	75.9	77.0	66.2	57.9	44.0	42.1	54.9	34.0	52.4	74.7	56.0	1851-2
1853	34.8	38.5	43.9	54.4	65.0	75.6	77.1	76.2	70.1	53.7	49.7	38.2	56.4	38.5	54.4	76.3	57.8	1852-3
1854	36.1	38.3	45.5	50.2	65.0	73.1	79.4	76.4	71.6	57.9	51.6	35.4	56.6	37.5	53.6	76.3	60.4	1853-4
1855	39.1	30.7	40.6	58.9	65.5	72.3	79.1	76.9	70.2	63.9	49.6	39.4	57.1	35.1	55.0	76.1	61.2	1854-5
1856	26.3	28.4	35.3	56.2	63.3	76.6	80.8	75.0	68.8	56.5	47.2	35.9	54.1	31.4	51.6	77.5	57.5	1855-6
1857	25.9	43.1	41.5	47.7	63.0	72.5	76.5	75.4	68.9	55.9	46.4	43.8	55.0	35.0	50.7	74.8	57.1	1856-7
1858	43.9	33.5	43.4	55.4	61.3	77.7	79.1	75.8	67.8	58.7	43.9	41.9	56.8	40.4	53.4	77.5	56.8	1857-8
1859	37.3	38.7	49.5	54.2	64.9	70.7	76.2	75.1	68.0	52.4	48.4	32.8	55.6	39.3	56.2	74.0	56.3	1858-9
1860	33.7	32.7	46.2	52.1	64.9	70.7	76.7	75.8	65.1	56.2	45.6	33.8	54.4	33.1	54.4	74.4	55.6	1859-60
1861	32.7	39.1	44.4	54.6	58.5	73.5	74.8	72.7	69.1	59.1	44.7	37.8	55.0	35.2	52.5	73.7	57.6	1860-1
1862	34.2	31.4	39.9	51.5	61.9	69.1	74.6	75.9	69.3	58.1	42.8	36.7	53.7	34.5	51.1	73.2	56.7	1861-2
1863	36.2	32.4	38.0	49.9	64.6	70.9	77.1	77.8	64.3	52.7	46.2	34.3	53.6	35.1	50.8	75.3	54.4	1862-3
1864	37.9	40.4	43.4	52.5	68.8	74.7	78.3	79.5	69.5	57.2	48.5	37.7	57.3	37.5	54.9	77.5	58.4	1863-4
1865	32.6	36.1	50.3	59.1	68.2	77.3	79.4	76.1	74.1	58.1	47.8	39.8	58.2	35.5	59.2	77.6	60.0	1864-5
1866	33.4	38.0	44.9	57.1	64.1	73.3	79.1	71.6	70.8	58.1	51.5	35.6	56.4	37.1	55.4	74.7	60.1	1865-6
1867	28.5	30.6	39.8	58.3	61.6	73.7	77.9	76.3	69.6	58.6	49.7	34.4	55.7	31.6	53.2	76.0	59.3	1866-7
1868	32.9	30.0	43.1	51.2	62.8	74.1	83.2	79.0	70.0	55.8	48.4	34.5	55.3	32.4	52.4	78.8	58.1	1867-8
1869	40.8	41.0	42.5	55.9	62.3	74.5	78.1	76.6	70.1	53.1	43.2	40.5	56.5	38.8	53.6	76.4	55.5	1868-9
1870	42.9	37.7	41.1	56.3	65.9	78.8	83.5	80.6	71.1	59.4	48.4	37.5	58.5	40.4	54.4	81.0	59.6	1869-70

Table xix Con't.—MEAN TEMPERATURES AT BALTIMORE FOR 88 YEARS, 1817-1904.

Years.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Winter	Spring	Summer	Autumn	Seasons
1871	35.3	39.8	47.7	58.9	65.4	74.0	76.0	77.5	63.7	58.7	45.2	33.8	56.2	37.5	57.3	75.8	55.9	1870-1
1872	34.4	36.0	37.0	55.3	67.2	75.3	81.7	79.8	69.5	56.9	43.7	32.4	55.7	34.7	53.2	78.9	56.7	1871-2
1873	34.2	35.6	40.4	52.0	62.3	73.9	79.6	76.6	68.3	55.3	41.5	40.7	55.0	34.1	51.6	76.7	55.5	1872-3
1874	39.3	37.4	43.8	47.0	63.1	75.9	77.5	73.1	70.2	57.1	45.8	39.3	55.8	39.1	51.3	75.5	57.7	1873-4
1875	30.3	29.4	39.6	49.5	64.1	73.7	78.2	73.7	66.2	56.0	43.4	38.6	53.5	33.0	51.1	75.2	55.2	1874-5
1876	41.7	37.9	39.9	52.2	64.2	75.9	80.6	76.2	65.9	52.9	47.6	29.0	55.3	39.4	52.1	77.6	55.5	1875-6
1877	32.3	40.6	41.5	53.7	62.7	73.7	78.9	77.9	68.2	60.2	48.4	43.8	56.8	34.0	52.6	76.8	58.9	1876-7
1878	34.9	40.4	49.2	58.6	63.5	70.2	80.8	76.0	69.7	58.8	47.4	35.6	57.1	39.7	57.1	75.7	58.6	1877-8
1879	31.5	32.2	43.8	52.8	65.7	73.3	79.0	75.3	65.2	63.0	46.7	41.9	55.8	33.1	54.1	75.9	58.3	1878-9
1880	42.9	41.2	42.8	55.1	70.8	75.3	77.7	74.7	68.3	56.0	42.0	31.3	56.4	42.0	56.2	75.9	55.4	1879-80
1881	30.3	34.6	41.8	51.7	67.8	70.8	78.9	77.2	77.2	63.5	49.3	43.8	57.2	32.1	53.8	75.6	63.3	1880-1
1882	34.7	41.3	45.0	52.1	59.6	74.0	76.9	74.2	69.3	61.9	44.5	36.7	55.8	39.9	52.2	75.0	58.6	1881-2
1883	32.3	39.1	39.5	52.2	64.2	74.6	77.1	73.2	65.4	57.9	48.4	39.0	55.2	36.0	52.0	75.0	57.2	1882-3
1884	32.0	42.2	44.1	52.4	65.0	73.2	75.4	75.5	72.4	60.6	46.6	37.4	56.3	37.7	53.8	74.7	59.9	1883-4
1885	34.0	28.5	35.4	54.3	63.2	72.6	79.9	74.9	67.2	55.8	45.8	37.6	54.0	33.3	51.0	75.8	56.3	1884-5
1886	29.1	31.3	41.7	54.7	62.1	69.9	74.7	73.8	69.9	59.0	46.6	31.3	53.6	32.7	52.8	72.8	58.5	1885-6
1887	32.4	38.2	37.9	51.3	67.6	72.3	80.6	73.6	65.0	56.3	45.3	37.2	54.7	34.0	52.3	75.5	55.5	1886-7
1888	29.1	35.5	37.4	52.7	62.8	73.2	74.6	76.5	65.1	53.0	48.3	37.2	54.1	33.9	51.0	74.8	55.5	1887-8
1889	38.7	30.6	44.1	54.8	65.7	71.2	76.5	73.7	66.3	54.1	47.9	45.1	55.6	35.5	54.9	73.8	56.1	1888-9
1890	43.7	43.0	40.9	53.9	63.7	75.1	76.3	74.1	67.8	57.0	47.5	34.9	56.4	43.9	52.8	75.2	57.4	1889-90
1891	37.3	41.6	39.0	56.0	62.1	71.7	71.6	74.5	70.5	54.4	43.9	43.0	55.4	37.9	52.4	72.6	56.3	1890-1
1892	31.9	36.2	37.3	51.9	63.1	75.5	76.8	76.4	66.7	56.0	44.0	33.7	54.0	37.0	50.8	76.2	55.6	1891-2
1893	24.3	34.0	40.4	52.5	61.6	72.5	76.8	75.6	65.9	57.1	43.9	38.1	53.4	30.7	51.5	75.0	55.6	1892-3
1894	37.4	34.4	47.8	52.3	64.8	73.1	77.4	73.7	69.9	57.4	43.3	37.3	55.6	36.6	55.0	74.7	56.9	1893-4
1895	31.4	26.2	40.2	52.8	62.5	74.3	73.1	77.2	71.7	53.4	47.0	38.7	54.0	31.6	51.8	74.9	57.4	1894-5
1896	33.3	35.2	37.8	56.5	68.7	71.3	77.7	77.0	68.0	54.3	50.9	36.2	55.5	35.7	54.3	75.3	57.7	1895-6
1897	30.8	36.6	45.2	52.6	63.4	69.9	77.0	74.9	68.9	58.5	46.2	38.5	55.2	34.5	53.7	73.9	57.9	1896-7
1898	36.7	34.7	48.6	51.4	63.5	73.7	78.6	77.7	71.2	59.0	44.6	36.2	56.2	36.6	54.5	76.7	58.3	1897-8
1899	32.7	28.0	41.6	53.6	64.8	75.3	77.1	76.0	66.5	59.0	46.7	36.8	54.8	32.3	53.3	76.1	57.4	1898-9
1900	35.3	33.1	38.6	54.8	64.9	72.9	79.6	80.3	73.5	62.0	49.5	36.6	56.6	35.1	52.8	77.6	61.7	1899-00
1901	24.4	28.7	42.9	51.0	62.0	73.5	79.8	76.9	68.5	56.1	41.8	34.7	54.1	33.2	52.0	76.7	55.5	1900-1
1902	31.5	29.8	46.2	53.2	63.9	71.9	77.2	74.1	67.7	58.6	51.7	35.3	55.0	32.0	54.4	74.4	59.3	1901-2
1903	33.5	36.9	49.7	54.8	65.5	67.5	77.2	72.7	67.7	58.7	43.3	32.9	54.9	35.2	56.7	72.5	56.6	1902-3
1904	27.5	28.6	41.3	50.5	65.8	71.6	75.7	....	....	....	....	....	....	29.7	52.5	....	....	1903-4
Ten-Year Mean.														Ten-Year Means.				
1821-1830	36.3	37.7	46.1	55.7	65.5	75.0	78.6	78.0	69.8	57.3	48.3	40.8	57.4	38.3	55.8	77.2	58.5	1821-1830
1831-1840	34.1	35.8	43.7	54.2	64.2	72.6	77.7	75.4	67.1	55.3	45.1	35.3	55.0	35.1	54.0	75.2	55.8	1831-1840
1841-1850	36.7	35.1	42.3	54.3	62.0	72.6	77.4	75.9	68.6	54.6	46.3	37.5	55.3	36.4	52.9	75.3	56.5	1841-1850
1851-1860	34.7	36.3	43.8	53.4	64.2	73.3	78.0	75.8	68.6	57.1	47.4	37.7	55.8	36.2	53.8	75.7	57.7	1851-1860
1861-1870	35.2	35.7	42.7	54.6	63.9	74.0	78.6	76.6	69.8	57.0	47.1	36.9	56.0	35.9	53.7	76.4	58.0	1861-1870
1871-1880	35.7	37.0	42.6	53.5	64.9	74.1	79.0	76.1	67.5	57.5	45.2	36.6	55.8	36.4	53.7	76.4	56.7	1871-1880
1881-1890	33.6	36.4	40.8	53.0	64.2	72.7	77.1	74.7	68.6	57.9	47.0	38.0	55.3	36.0	52.7	74.8	57.8	1881-1890
1891-1900	33.1	34.0	41.6	53.4	63.9	73.0	76.6	76.3	69.3	57.1	46.0	37.5	55.1	34.9	53.0	75.3	57.5	1891-1900
Gen'l Averages.																		
1817-1870	35.4	36.1	43.6	54.6	63.8	73.5	78.1	76.4	68.7	56.0	47.0	37.7	55.9	36.4	54.0	76.0	57.2	1817-1870
1871-1903	34.0	35.5	42.1	53.3	64.3	73.1	77.6	75.6	68.4	57.5	46.0	37.1	55.3	35.5	53.2	75.4	57.3	1871-1903
1817-1903	34.9	35.8	43.1	54.1	64.0	73.3	77.9	76.1	68.6	56.6	46.6	37.4	55.6	36.0	53.7	75.8	57.3	1817-1903

Table XIX shows the mean monthly, seasonal and annual temperature for Baltimore for 88 years from 1817 to 1904. The table contains three distinct records: (a) observations from 1817 to 1824, by Capt. Lewis Brantz, in what was then west Baltimore; (b) observations at Fort McHenry, along the Baltimore harbor, from 1831 to 1870; (c) observations under the auspices of the United States Weather Bureau from 1871 to 1904.



DEPARTURES OF MEAN MONTHLY, SEASONAL AND ANNUAL TEMPERATURE FROM NORMAL FOR 87 YEARS.

The Lewis Brantz observations were reduced to the Fort McHenry series by applying corrections derived from an overlapping period in 1836 and 1837. The monthly means for the period from 1825 to 1830 were derived from Washington, D. C., observations, and reduced to the Fort McHenry series by adding the departures from the Washington, D. C., normal temperatures to the Fort McHenry normal. The means for the years 1859 to 1863 were reduced to the Fort McHenry series in a similar manner by means of a 20-year record of overlapping observations made at Shellman's Hills, about 20 miles west of Baltimore. The record from 1817 to 1870 was then made conformable to the Weather Bureau record from 1871-1903 by means of departures derived from overlapping records covering a period of about 20 years. Thus the entire record from 1817 to 1903 may be regarded as an approximately uniform series of Baltimore City temperatures.

THE NORMAL TEMPERATURE.

The variations of the mean monthly, seasonal and annual temperature during the greater portion of the preceding century are discussed in succeeding pages, while the mean for each month, season and year since 1817 is published in Table XIX, together with the monthly, seasonal, and annual averages for each ten-year period, and for the entire 87 years. The variations in value of the ten-year averages are observed to be small, even in the case of the month of greatest variability. The maximum variability (5.3°), occurs in the month of March with a mean temperature, for a ten-year period, as low as 40.8° and as high as 46.1°.

The annual average for ten years has varied between the limits 55.0° and 57.4° a range of 2.4°. No progressive increase or decrease is indicated for the entire period either in the monthly, seasonal, or the annual means. From the third decade (1831-1840), there was a steady rise in temperature to the sixth (1861-1870), and since then a steady fall to the present time. The series of observations is not sufficiently long, however, to draw the conclusion that there is a periodic change of this length. In the absence of changes of long period in the fluctuations of the annual mean temperature the normal temperature derived from the 87 years will remain fixed at 55.6° for Baltimore. The probable error of this value is not greater than one-tenth of one degree Fahrenheit. Hence a longer series of observation will not change the result by an amount greater than one-tenth of one degree.

The Variability of the Monthly and Annual Mean.

In tabulating the following lists of exceptional months and seasons the sole basis of selection has been an average monthly temperature decidedly above or below the normal for the entire period of 87 years. Such lines of division must necessarily be arbitrary as there are no fixed standards of cold and warm. The degree of departure from the normal fixed upon for classification as cold or warm varied with the variability of the month and season. In the comparatively constant summer months a departure of 2° may be regarded as exceptional. In the variable winter months a departure of 6° may be assumed to be necessary to make the month an exceptionally cold or warm one. The seasons and the year being less fluctuating, the departures selected were smaller, varying from 2° for the year and the summer to 4° for the winter season.

A close examination of this list of exceptional departures from the normal will doubtless cause surprise by the absence of periods which left an impression of great heat or cold. Attention has already been called to the fact that an average temperature for the period of a month or season is sometimes an inadequate measure of the temperature conditions of the period. A month with 10 consecutive days of excessively hot weather for example, will long remain in memory as a hot month, no matter what the average temperature of the entire month may be. Yet a moderately cool spell preceding and following the hot days will result in an average value for the month little if any above the normal and hence would not be found in a list of warm months.

The month of July, 1898, may be cited as a case in point. The highest temperature recorded in the official records of the Baltimore station occurred on July 3, 1898, namely 104°. The month contained 10 days with a temperature of 90° and over. Yet this month is not listed as a *warm* month because the *average* temperature for the entire month was less than 2° above the normal. The proper place to look for such excessively hot spells is in the list of warm *days* rather than warm *months*. As a rule, however, the average temperature is a safe guide for expressing the general temperature conditions of a given period.

Warm Months and Seasons.

The following list includes the months and seasons since 1817 during which the *average* temperature rose decidedly above the normal in the vicinity of Baltimore. The degree of departure required for each month and season in order to find a place in the list is shown in the column headed "Departure."

WARM MONTHS AND SEASONS.

	Departure.	
January	6°+	1824, 1828, 1843, 1870, 1876, 1880, 1890.
February	6°+	1820, 1827, 1828, 1834, 1857, 1884, 1890.
March	6°+	1825, 1826, 1842, 1859, 1865, 1878, 1903.
April	5°+	1817, 1822, 1823, 1827, 1865.
May	4°+	1822, 1826, 1833, 1848, 1864, 1865, 1880, 1896.
June	4°+	1828, 1858, 1865, 1870.
July	3°+	1822, 1830, 1834, 1838, 1868, 1870, 1872.
August	3°+	1819, 1821, 1822, 1827, 1828, 1870, 1872, 1900.
September	4°+	1822, 1826, 1865, 1881, 1900.
October	4°+	1855, 1879, 1881, 1882, 1884, 1900.
November	4°+	1818, 1822, 1830, 1849, 1850, 1866, 1896, 1902.
December	5°+	1824, 1827, 1829, 1848, 1857, 1877, 1881, 1889, 1891.
Winter	4°+	1823-4, 1824-5, 1827-8, 1849-50, 1850-1, 1857-8, 1869-70, 1879-80, 1889-90.
Spring	3°+	1822, 1826, 1827, 1831, 1833, 1865, 1871, 1878, 1903.
Summer	2°+	1819, 1821, 1822, 1827, 1828, 1830, 1838, 1868, 1870, 1872.
Autumn	3°+	1822, 1830, 1854, 1855, 1881, 1900.
Year	2°+	1822, 1825, 1826, 1827, 1828, 1830, 1865, 1870.

The years 1822, 1827, 1828, 1857 and 1870, are conspicuous in the list for sustained warmth during several months of the year. During 1822 there were five months of the year with an excessive departure above the normal. During one month only, namely January, was the temperature below the normal. The year attained the highest mean annual temperature on record, namely 3.2° above the normal.

COLD MONTHS AND SEASONS.

	Departure.	
January	6°+	1821, 1840, 1856, 1857, 1858, 1867, 1893, 1904.
February	6°+	1829, 1836, 1838, 1856, 1875, 1885, 1895, 1899, 1901, 1902, 1904.
March	6°+	1836, 1843, 1856, 1872, 1885.
April	5°+	1821, 1841, 1857, 1874.
May	4°+	1820, 1838, 1841, 1843, 1861, 1882.
June	4°+	1836, 1846, 1862, 1903.
July	3°+	1829, 1840, 1861, 1862, 1886, 1888, 1891, 1895.
August	3°+	1836, 1861, 1866, 1903.
September	4°+	1835, 1840, 1863, 1871.
October	4°+	1819, 1820, 1834, 1836, 1838, 1841, 1844, 1859.
November	4°+	1820, 1836, 1838, 1839, 1842, 1844, 1873, 1880, 1901.
December	5°+	1831, 1840, 1845, 1872, 1876, 1880, 1886.
Winter	4°+	1855-6, 1866-7, 1892-3, 1894-5, 1901-2, 1903-4.
Spring	3°+	1836, 1841, 1843, 1857.
Summer	2°+	1836, 1842, 1846, 1861, 1862, 1886, 1889, 1891, 1903.
Autumn	3°+	1836, 1838, 1841, 1842, 1844.
Year	2°+	1836, 1841, 1863, 1875, 1886, 1893.

The year 1836 occurs most frequently in the list of cold months and seasons. The average temperature for the entire year was the lowest in the record of 87 years. It also contained lowest average August and October temperatures, and the lowest summer and autumn averages. January alone was above the normal, and this but 1.4° above. The temperaature was decidedly below the normal during nine months of the year. The summers of 1903 and 1886 follow close behind the memorable summer of 1836. The recent winter of 1903-04 with an average temperature of 29.7° was the coldest experienced in Baltimore. No excessively low temperatures were recorded, but the entire season was characterized by an almost unbroken period of moderately cold weather. There was an almost total absence of the usual and sometimes frequent "thaws" of previous years. The ice crop was the heaviest in many years. Navigation on the Bay was impeded to an unprecedented extent. The Bay was frozen from shore to shore to a distance of over 80 miles south of Baltimore.

WARMEST AND COLDEST MONTHS.

(Expressed in terms of departures from the normal.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Normal	34.9°	35.8°	43.1°	54.1°	64.0°	73.3°	77.9°	76.1°	68.6°	56.6°	46.6°	37.4°
Warmest +	+9.0	+10.5	+7.2	+7.8	+8.2	+5.5	+5.6	+4.9	+8.6	+7.3	+8.0	+8.2
Year	1858	1834	1865	1817	1826	1870	1870	1821	1881	1855	1849	1829
Coldest —	—10.6	—9.6	—11.9	—7.1	—4.9	—5.8	—6.3	—5.1	—6.5	—8.6	—6.7	—10.4
Year	1893	1895	1843	1874	1843	1903	1891	1836	1835	1836	1842	1831
Range	19.6	20.1	19.1	14.9	20.5	11.3	11.9	10.0	15.1	16.1	14.7	18.6

WARMEST AND COLDEST SEASONS AND YEARS.

	Winter.	Spring.	Summer.	Autumn.	Year.
Normal	36.0°	53.7°	75.8°	57.3°	55.6°
Warmest +	+7.9	+5.5	+5.2	+6.0	+3.2
Year	1889-90	1865	1870	1881	1822
Coldest —	—6.3	—8.9	—4.2	—4.2	—3.8
Year	1903-4	1843	1836	1836	1836
Range	14.2	14.4	9.4	10.2	7.0

Winter and spring have varied most from the normal, the difference between the warmest winter (namely 43.9° in 1889-90) and the coldest winter (29.7° in 1903-04) is 14.2°. The spring limits are + 5.5° (1865) and — 8.9° (1843), a range of 14.4°. The summer limits are + 5.2°

(1870) and —4.2° (1836), a range of 9.4°. The autumn limits are + 6.0° (1881) and — 4.2° (1836), a range of 10.2°.

A warm February may have the average temperature of a normal March, or approach that of a cold April, or cold October. A warm September may have the average temperature of a normal July or August. October has been nearly as cold as a warm February. May has been as warm as a cold July. A month may have the same mean temperature as the second preceding or following month. Hence a season may be one month later or earlier than the average time, or, there may be two months difference for example, between a very late spring and a very early spring.

Frequency of Stated Departures from the Monthly Seasonal and Annual Mean Temperatures.

During a period of 87 years the mean annual temperature was below the arithmetical average in 45 per cent of the total number of years, above the normal in 49 per cent, and exactly normal (within one-tenth of a degree Fahrenheit) in 6 per cent.

THE DISTRIBUTION OF SEASONAL DEPARTURES.

	Above Normal.	Below Normal.	Normal.
	%	%	%
Winter	41	59	0
Spring	48	51	1
Summer	45	52	3
Autumn	46	54	0
Average	45	54	1

These figures indicate that the average seasonal temperatures are most likely to be below the normal value; hence the average plus departure must be larger than the minus departure. This discrepancy between the departures of opposite sign is most conspicuous in the January temperatures with departures above the normal in 41 per cent of the past 87 years, and below in 59 per cent. A further interesting feature of the tabulation above is that the exact average value seldom occurs. Computing the averages to tenths of a degree Fahrenheit, the normal value has never been experienced in 87 years in winter and autumn, but once in spring, and three times in summer. The annual normal has occurred five times. Hence the arithmetical average seasonal temperatures are not the most probable or of the

most frequent occurrence. The most probable departure differs with the month and the season.

The following table shows the frequency of departures of stated values from the normal monthly and annual temperature during the 87 years from 1817 to 1903. The total number of values included is over 1000. For example, taking the month of January, the monthly mean temperature has been colder or warmer than the normal by 1° or less 17 times in the 87 years past; it was 3° warmer or colder 16 times; 6° 7 times; 11° once, etc. The frequency of stated monthly departures is also shown in Fig. 22, and the seasonal and annual departures in Fig. 23, as percentages of total number of occurrences.

FREQUENCY OF DEPARTURES FROM NORMAL MONTHLY TEMPERATURES.

Departures.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.	Total Annual
± 1	17	11	21	18	36	36	33	36	30	21	20	24	45	304
2	13	11	17	22	22	13	30	25	21	18	22	16	32	229
3	16	11	10	20	10	24	11	14	17	24	12	11	8	180
4	9	13	11	10	6	7	9	7	10	12	17	12	2	123
5	12	11	7	10	6	4	1	4	6	3	8	9	....	80
6	7	14	10	3	1	3	2	1	1	4	5	3	....	55
7	4	4	6	2	3	....	1	....	1	2	1	5	....	30
8	2	9	3	2	1	....	....	....	....	2	2	3	....	24
9	6	....	....	....	1	....	....	....	1	1	....	3	....	11
10	....	2	1	....	....	....	..	....	....	....	....	....	..	3
11	1	1	1	....	....	....	....	....	....	....	....	1	....	4
12	....	....	....	....	....	....	....	....	....	....	....	....	....	0
±13	....	....	....	....	1	...	....	....	....	....	....	....	....	1
Plus Departures (+)	35	47	44	44	40	43	39	44	44	45	43	43	42	511
Minus Departures (—)	50	40	41	43	46	43	44	42	43	42	42	43	40	519
No Departures (0)	2	0	2	0	1	1	4	1	0	0	2	1	5	14

In most months the departure is likely to be about 1° above or below the normal; in April the most probable departure is 2°, in October 3°, and in February above 4°.

Fifty-two per cent of the mean annual temperatures have fallen within 1° of the normal value in the past 87 years, and in 37 per cent of the remaining years the mean was within 2° of the normal. No annual mean has risen to 4° above the normal and none fallen 4° below. Hence the annual mean temperature has a comparatively small range of departure from the normal. The extreme departures occurred in 1822 (3.2° above normal) and in 1836 (3.8° below), an extreme range of 7° between

the coldest and warmest years on record at Baltimore. The frequency of departures of stated values for the seasons is shown in the following table, in percentages of the total occurrences in 87 years:

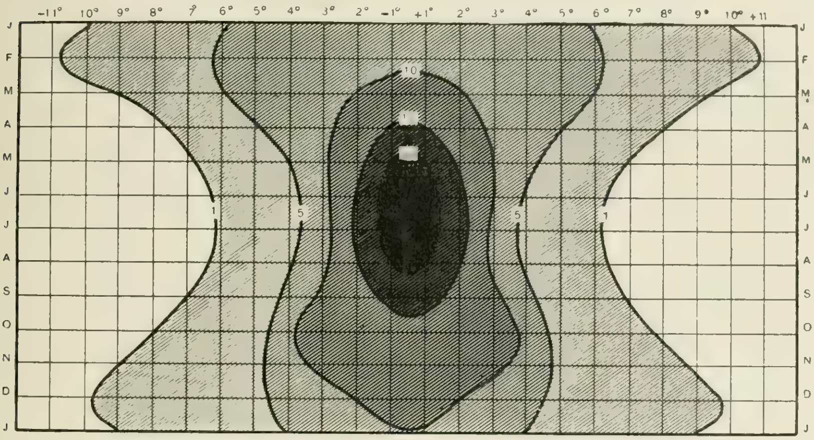


FIG. 22.—Frequency of Stated Departures from the Monthly Normal Temperature.

Fig. 22 shows the frequency of stated departures from the normal value of the monthly temperatures, based on records covering 87 years. The upper line of figures represents the degree of departure above (+) or below (—) the normal monthly temperature. The marginal letters represent the months of the year. The curved lines and shaded areas represent the frequency of the changes expressed as percentages of total number of months. Increase in intensity of shading represents increase in the frequency of stated changes. For example, changes of + 2 or — 2 occurred in 10 per cent. of the total number of instances in March, 20 per cent. in May and August, 10 per cent. in December, etc. See also Fig. 23.

FREQUENCY OF STATED SEASONAL DEPARTURES.

	1°	2°	3°	4°	5°	6°	7°	8°	9°	Above 3°
	%	%	%	%	%	%	%	%	%	%
Winter	19	29	17	19	10	2	2	2	0	35
Spring	32	27	26	8	4	2	0	0	1	15
Summer	46	32	14	6	1	1	....	....	....	8
Autumn	33	34	20	8	4	0	1	....	....	13

	Winter	Spring	Summer	Autumn	Average
The arithmetical average departure......	3.4°	2.6°	1.7°	2.3°	2.5°
The most frequent departure	2.0°	1.0°	1.0°	2.0°	1.5°

THE PROBABLE ERROR OF THE MONTHLY AND ANNUAL MEANS.

Employing the formula given in a preceding paragraph for the determination of the probable error of the daily mean temperature in order to

arrive at the probable error of the monthly and annual means for the series of 87 years we obtain the following values:

AVERAGE MONTHLY AND ANNUAL DEPARTURES AND PROBABLE ERROR OF THE MONTHLY AND ANNUAL MEAN TEMPERATURES.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Average departure (v)..	3.4°	3.9°	3.1°	2.5°	2.1°	1.8°	1.6°	1.6°	2.0°	2.4°	2.5°	2.9°	1.1°
Probable error (E)...........	.32	.36	.28	.23	.20	.16	.15	.15	.18	.21	.23	.26	.10

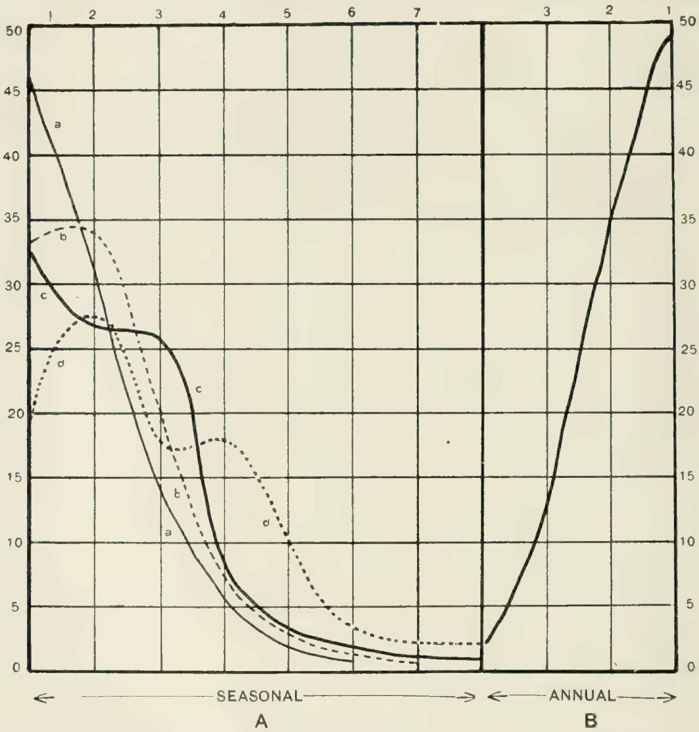


FIG. 23.—Frequency of Stated Departures from the Normal Seasonal (*A*) and Annual (*B*) Temperatures. (*a*) Summer, (*b*) Autumn, (*c*) Spring, (*d*) Winter.

Fig. 23 shows the frequency of stated departures from the normal seasonal (A) and annual (B) temperatures. The upper horizontal row of figures indicates the degree of change, and the vertical rows to the right and left of the diagram indicate the frequency of change, expressed as percentages of the total number of seasonal and annual changes from 1817 to 1903.

The probable error of the mean annual temperature is about one-half that of the mean monthly temperature; the probable error of the latter is

about one-fourth that of the mean daily temperature. Hence the probable error of the daily mean is eight times as large as that of the annual mean.

Succession of the Seasons.

It may be definitely stated, as the result of a study of the Baltimore temperature observations for 87 years, that there is no regular periodic recurrence of cold and warm periods. Some interesting questions in probabilities are, however, suggested by a classification of the decidedly cold and warm seasons, in connection with the character of succeeding seasons. This has been done in the following manner: A winter was regarded as cold or warm when the departure from the average winter condition equalled or exceeded 2°; when less than 2° it was considered a normal season. The point of departure for the spring and autumn was 1.5°, for the summer and for the year 1.0°. This classification yielded from 20 to 25 abnormal seasons of each class during a period of 87 years. For each of the abnormal winters the character of the succeeding spring, summer, autumn and winter was then noted. Abnormal summers and abnormal years were tabulated in a similar manner, with the following result:

SUCCESSION OF THE SEASONS.

	Total number.	Spring (±1.5°+).			Summer (±1.0°+).			Autumn (±1.5°+).			Winter (±2.0°+).		
		Cold.	Average.	Warm.	Cold.	Average.	Warm.	Cold.	Average.	Warm.	Cold.	Average.	Warm.
Cold Winters (−2.0°+)	23	10	13	0	9	11	3	8	10	5	6	9	8
Warm Winters (+2.0°+)	22	3	9	10	2	11	9	6	11	5	6	11	5
		Autumn (±1.5°+).			Winter (±2.0°+).			Spring (±1.5°+).			Summer (±1.0°+).		
Cold Summers (−1.0°+)	25	7	15	3	9	12	4	11	12	1	10	12	2
Warm Summers (+1.0°+)	22	3	9	10	2	14	6	4	6	12	5	10	7
		Year.											
Cold Years (−1.0°+)	20	8	11	1	....	....	....	....	....	....	....	....	....
Warm " (+1.0°+)	24	3	11	10	....	....	....	....	....	....	....	....	....

Of 23 cold winters, 10 were followed by cold springs, 13 by average springs, and not one by a warm spring. Nine were followed by a cold summer, 11 by an average summer and only 3 by a warm summer. The succeeding winter was cold in 6 cases, average in 9 and warm in 8. These figures show a decided probability in favor of a cold or cool spring and summer following a cold winter, and of a cool autumn; there is no decided tendency as to the character of the succeeding winter. A similar tendency is shown in favor of a warm spring and summer after a warm winter. There is also a decided probability that a cold summer will be followed by a cold or a cool autumn, winter, spring, and next succeeding summer, and that a warm summer will be followed by a warm or an average autumn, winter, spring, and next succeeding summer.

More cautious, and perhaps safer, is the negative statement that a cold winter is not likely to be followed by a warm spring or summer; that a warm winter is not likely to be followed by a cold spring and summer. In general it may be said that an extreme season is not likely to be followed by an opposite extreme. Such a conclusion may not be regarded as of much practical value for determining the probable character of a coming season, but a more definite statement does not seem to be warranted by the statistical record.

Considering the average temperature for the entire year there were 20 cases of a departure of 1° or more below the normal. Of these 8 were followed by cold years, 11 by years of an average temperature, and 1 by a warm year. Of 24 warm years 3 were followed by cold years, 11 by average years, and 10 by warm years. Here again the same tendency is shown against the occurrence of a succession of years of opposite character. That is, a decidedly cold year is not likely to be followed by a decidedly warm year, or a warm year by a cold year. All such classifications are, however, arbitrary and inferences as to the succession of the seasons should be accepted with caution when based upon phenomena as variable in their nature as the climatic factors of the middle latitudes.

Daily Extremes of Temperature.

Thus far only average temperatures for a day, month, or year, have been considered, with departures from the normal conditions based on many

years of observations. The variability of a given climate is best illustrated, however, by extremes of temperature within given limits of time, and by the frequency of occurrence of stated changes from day to day.

TABLE XX.—DAILY EXTREMES OF TEMPERATURE. (SPRING.)

Date.	March. Max.	Year.	Min.	Year.	Extreme range.	April. Max.	Year.	Min.	Year.	Extreme range.	May. Max.	Year.	Min.	Year.	Extreme range.
1	72	1895	14	1884	58	78	1893	30	1887	48	87	1890	34	1876	53
2	69	1882	15	1886	54	82	1882	30	1876	52	87	1894	37	1903	50
3	68	1871	12	1873	56	80	1892	29	1899	51	84	1878	38	1882	46
4	74	1880	5	1873	69	83	1892	29	1904	54	86	1892	40	1900	46
5	76	1880	9	1872	67	77	1880	25	1881	52	84	1896	42	1875	42
6	72	1894	13	1901	59	75	1892	26	1898	49	86	1880	40	1891	46
7	72	1878	12	1890	60	75	1890	30	1898	45	88	1872	44	1882	44
8	65	1878	12	1873	53	85	1871	32	1896	53	89	1900	42	1898	47
9	67	1871	21	1885	46	82	1871	32	1885	50	93	1896	40	1898	53
10	70	1897	17	1877	53	84	1887	32	1894	52	96	1896	42	1900	54
11	71	1879	20	1892	51	85	1887	30	1882	55	94	1896	45	1877	49
12	76	1890	12	1900	64	76	1899	27	1874	49	94	1881	44	1885	50
13	75	1890	12	1888	63	83	1890	29	1874	54	95	1881	40	1895	55
14	66	1903	14	1888	52	85	1896	34	1885	53	91	1900	46	1895	45
15	71	1886	21	1900	50	82	1891	32	1904	50	94	1900	42	1895	52
16	68	1886	18	1893	50	86	1896	36	1893	50	87	1900	43	1904	44
17	72	1898	15	1900	57	89	1896	27	1875	62	93	1896	44	1891	49
18	68	1894	9	1877	59	94	1896	26	1875	68	92	1896	46	1895	46
19	78	1894	12	1876	66	93	1896	24	1875	69	92	1877	47	1895	45
20	69	1903	12	1885	57	87	1896	27	1904	60	92	1903	48	1899	44
21	72	1897	12	1885	60	83	1896	32	1875	51	88	1893	44	1895	44
22	82	1894	19	1885	63	89	1902	32	1875	57	88	1903	42	1895	46
23	71	1871	16	1888	55	88	1902	36	1875	52	90	1902	47	1892	43
24	66	1903	18	1896	48	88	1886	38	1888	50	89	1884	46	1892	43
25	70	1904	21	1878	49	86	1895	34	1883	52	90	1880	46	1877	44
26	66	1896	21	1878	45	88	1872	37	1883	51	92	1880	45	1886	47
27	69	1903	20	1894	49	82	1891	39	1893	43	93	1880	48	1897	45
28	77	1890	24	1894	53	81	1888	34	1898	47	90	1899	46	1902	44
29	77	1902	23	1887	54	90	1888	33	1874	57	89	1895	43	1894	46
30	69	1896	21	1887	48	91	1903	34	1874	57	95	1895	46	1884	49
31	74	1888	29	1873	45	....	....	....	....	....	95	1895	50	1873	45

Table XX shows the highest and lowest temperatures recorded on each day of the year during 34 years from 1871 to June, 1904, with year of occurrence, and the extreme range for the day.

In Table XX, and in curves A, C, and D of Plate IV, the highest and lowest temperatures officially recorded upon each day of the year during a period of 33 years are shown, together with the absolute daily range. In addition the table shows the year of occurrence of the extremes. A study of the curves of Plate V will most clearly and quickly reveal the extremely changeable character of the temperature from day to day, and the

relative variability of the seasonal changes. The changes in the *average* temperatures from day to day throughout the year have already been described in preceding sections of this report. As the average temperatures were derived from the daily extremes, there must of necessity be a general agreement, with a difference only in the amplitude of change.

Table xx Con't.—DAILY EXTREMES OF TEMPERATURE. (SUMMER.)

Date.	June. Max.	Year.	Min.	Year.	Extreme range.	July. Max.	Year.	Min.	Year.	Extreme range.	August. Max.	Year.	Min.	Year.	Extreme range.
1	97	1895	47	1894	50	103	1901	56	1885	47	95	1890	57	1895	38
2	95	1895	48	1897	47	103	1901	59	1891	44	92	1879	58	1875	34
3	97	1895	52	1888	45	104	1898	59	1888	45	92	1881	59	1895	33
4	91	1890	53	1888	38	100	1898	59	1891	41	94	1888	58	1886	36
5	93	1899	52	1886	41	96	1881	58	1892	38	96	1896	59	1874	37
6	98	1899	47	1894	51	96	1901	58	1891	38	97	1900	60	1894	37
7	96	1899	47	1894	49	96	1900	60	1891	36	100	1900	62	1897	38
8	96	1874	47	1891	49	98	1890	55	1891	43	99	1900	58	1903	41
9	98	1874	50	1891	48	99	1876	56	1891	43	100	1900	62	1887	38
10	90	1879	52	1904	38	97	1880	56	1894	41	100	1900	56	1879	44
11	92	1893	50	1904	42	96	1876	57	1898	39	100	1900	58	1879	42
12	95	1880	52	1887	43	96	1876	57	1895	39	99	1900	60	1890	39
13	94	1902	53	1903	41	99	1880	57	1888	42	98	1881	56	1902	42
14	95	1885	53	1873	42	95	1887	58	1895	37	96	1872	57	1893	39
15	93	1891	53	1884	40	96	1900	57	1895	39	90	1900	59	1887	31
16	94	1891	52	1884	42	101	1887	59	1903	42	96	1888	58	1889	38
17	93	1887	55	1899	38	100	1900	59	1892	41	92	1900	55	1902	37
18	94	1887	54	1879	40	102	1887	60	1892	42	91	1900	60	1874	31
19	93	1893	56	1886	37	96	1878	61	1890	35	93	1872	59	1896	34
20	98	1893	55	1879	43	98	1885	57	1890	41	97	1899	54	1896	43
21	93	1896	56	1897	37	99	1885	55	1890	44	97	1899	55	1876	42
22	94	1888	54	1897	40	96	1899	56	1890	40	96	1872	56	1876	40
23	97	1894	55	1898	42	95	1883	59	1890	36	93	1898	55	1888	38
24	98	1894	54	1902	44	95	1884	59	1876	36	94	1898	51	1890	43
25	98	1898	55	1902	43	97	1892	59	1876	38	97	1903	56	1879	41
26	97	1875	61	1893	36	99	1892	61	1891	38	96	1900	52	1874	44
27	95	1876	57	1893	38	97	1892	59	1876	38	92	1900	53	1885	39
28	94	1898	56	1897	38	97	1894	59	1893	38	91	1895	53	1885	38
29	97	1874	55	1888	42	97	1892	62	1897	35	94	1877	52	1874	42
30	99	1901	57	1899	42	95	1903	60	1880	35	91	1898	54	1896	37
31	...	...	...	...	...	95	1890	55	1895	40	95	1898	55	1887	40

The greatest variability in extreme conditions occurs in the winter months, with a gradual decrease to more uniform conditions toward summer. The greatest change of temperature which has been recorded within a period of 24 hours during 33 years at Baltimore is 47°. This remarkable range between the highest and lowest temperature of a single day occurred on the 24th of February, 1900. When we consider extremes which have

occurred upon a given date, without reference to the year of occurrence, the range is greatly increased. For instance, upon the 11th of February a maximum temperature of 72° was recorded in 1887, and a minimum of 6° below zero in 1899, a range of 78°. Even in the months of least vari-

Table xx Con't.—DAILY EXTREMES OF TEMPERATURE. (AUTUMN.)

Date.	September.					October.					November.				
	Max.	Year.	Min.	Year.	Extreme range.	Max.	Year.	Min.	Year.	Extreme range.	Max.	Year.	Min.	Year.	Extreme range.
1	95	1898	56	1887	39	89	1881	39	1899	50	74	1903	31	1873	43
2	96	1898	50	1892	46	88	1881	38	1899	50	76	1876	32	1873	44
3	97	1898	51	1893	46	89	1879	36	1899	53	75	1903	32	1875	43
4	91	1898	50	1872	41	87	1884	38	1888	49	75	1903	28	1879	47
5	91	1880	50	1872	41	85	1884	42	1901	43	72	1896	25	1879	47
6	94	1900	51	1883	43	89	1884	36	1892	53	74	1888	31	1892	43
7	101	1881	51	1883	50	81	1884	40	1892	41	68	1896	28	1903	40
8	94	1872	55	1892	39	82	1887	38	1876	44	73	1890	28	1886	45
9	94	1894	51	1891	43	84	1893	37	1896	47	77	1895	29	1886	48
10	98	1884	46	1883	52	85	1887	35	1895	50	74	1879	31	1874	43
11	97	1897	49	1875	48	79	1898	40	1881	39	72	1899	31	1901	41
12	93	1895	51	1879	42	82	1889	33	1876	49	78	1879	27	1894	51
13	93	1897	53	1902	40	80	1884	35	1876	45	76	1902	28	1873	48
14	89	1903	48	1902	41	82	1883	34	1875	48	68	1889	26	1873	42
15	92	1901	40	1873	52	82	1897	33	1876	49	75	1902	28	1883	47
16	89	1897	41	1873	48	90	1897	30	1876	60	75	1897	23	1883	52
17	90	1886	49	1887	41	82	1879	36	1893	46	75	1896	25	1883	50
18	91	1898	48	1875	43	84	1881	36	1876	48	71	1896	22	1891	49
19	94	1896	47	1875	47	76	1899	35	1880	41	74	1900	21	1891	53
20	90	1895	49	1875	41	76	1884	36	1900	40	68	1900	23	1879	45
21	96	1895	45	1897	51	77	1884	39	1900	38	79	1900	21	1879	58
22	96	1895	44	1873	52	78	1901	34	1899	44	71	1883	15	1880	56
23	95	1895	46	1896	49	81	1901	36	1889	45	68	1900	16	1880	52
24	87	1881	43	1875	44	79	1900	34	1889	45	70	1896	17	1880	53
25	90	1881	42	1887	48	80	1902	33	1879	47	65	1890	24	1881	41
26	93	1895	40	1879	53	77	1891	30	1879	47	71	1896	21	1903	50
27	90	1881	43	1879	47	75	1899	35	1903	40	74	1896	18	1903	56
28	91	1886	44	1899	47	77	1899	34	1898	43	71	1896	20	1903	51
29	87	1884	43	1903	44	78	1874	31	1873	47	61	1879	23	1875	38
30	88	1881	39	1888	49	75	1903	30	1873	45	62	1899	16	1875	46
31						77	1896	31	1893	46					

ability the range is still large. The smallest range, namely 31°, is credited to August 14 and 18. The highest temperature of the year occurred on July 3, 1898, and the lowest on February 10, 1899. Although we have no systematic and official records of daily extremes of temperature prior to 1872, when self-registering maximum and minimum thermometers were added to the equipment of the U. S. Weather Bureau stations, we have good reason to believe that the period from 1872 to 1903 comprised

within its limits the warmest and coldest days experienced at Baltimore. In the summer of 1898 all existing records of high temperature were broken during the hot spell of July 1-4 within the State of Maryland. In the following winter during the first decade of February all existing

Table xx Con't.—DAILY EXTREMES OF TEMPERATURE. (WINTER.)

Date.	December.					January.					February.				
	Max.	Year.	Min.	Year.	Extreme range.	Max.	Year.	Min.	Year.	Extreme range.	Max.	Year.	Min.	Year.	Extreme range.
1	65	1881	16	1875	49	60	1885	—6	1881	66	63	1891	8	1900	55
2	65	1901	17	1886	48	71	1876	6	1899	65	58	1877	4	1881	54
3	67	1874	16	1886	51	57	1876	0	1879	57	61	1883	7	1895	54
4	73	1873	18	1886	55	67	1874	5	1879	62	66	1903	8	1886	58
5	60	1883	12	1871	48	61	1890	1	1877	60	71	1890	—1	1886	72
6	60	1879	16	1901	44	62	1890	5	1904	57	68	1884	1	1895	67
7	63	1896	15	1885	48	62	1874	9	1884	53	64	1904	6	1895	58
8	64	1892	10	1882	54	60	1898	6	1878	54	57	1892	2	1895	55
9	68	1889	4	1876	64	60	1876	6	1875	54	58	1878	2	1899	56
10	60	1897	1	1876	59	60	1876	—2	1875	62	61	1876	—7	1899	68
11	66	1897	13	1880	53	52	1891	2	1875	50	72	1887	—6	1899	78
12	70	1873	22	1895	48	70	1890	4	1886	66	65	1898	5	1899	60
13	69	1889	14	1895	55	73	1890	2	1886	71	66	1903	6	1899	60
14	71	1881	14	1898	57	58	1892	6	1886	52	63	1884	6	1899	57
15	62	1893	15	1900	47	63	1871	8	1893	55	67	1886	6	1899	61
16	63	1877	13	1876	50	64	1901	1	1893	63	67	1891	6	1875	61
17	63	1877	8	1876	55	65	1885	12	1893	53	73	1891	5	1896	68
18	58	1877	12	1875	46	64	1876	2	1893	62	71	1891	7	1903	64
19	62	1900	10	1884	52	63	1876	6	1904	57	60	1887	5	1903	55
20	67	1877	7	1871	60	63	1880	14	1901	49	60	1887	8	1896	52
21	61	1885	5	1871	56	55	1901	13	1893	42	72	1874	8	1885	64
22	70	1889	6	1872	64	65	1874	8	1893	57	74	1874	13	1896	61
23	67	1891	17	1872	50	69	1874	11	1883	58	78	1874	12	1889	66
24	62	1893	8	1872	54	57	1894	7	1882	50	61	1872	2	1873	59
25	67	1893	8	1872	59	61	1879	8	1897	53	66	1871	8	1900	58
26	73	1889	12	1903	61	58	1878	8	1897	50	74	1890	15	1900	59
27	63	1881	11	1903	52	64	1890	13	1888	51	64	1880	9	1900	55
28	61	1889	13	1872	48	69	1876	10	1888	59	71	1903	13	1888	58
29	63	1893	4	1880	59	64	1876	6	1873	58	67	1880	10	1884	57
30	66	1898	—3	1880	69	59	1896	—4	1873	63	....	......	....	.....	.....
31	66	1884	—1	1880	67	53	1880	8	1873	45	....	......	....	.....	.....

records of great cold were lowered. The variability of temperature conditions during the past five or six years has been phenomenal. Records of extremes of temperature which have remained undisturbed for many years were broken to a remarkable extent. In addition to the instances of absolute extremes of temperature just referred to, may be mentioned the high monthly average temperature of March, 1903, the warmest March in 87 years or more; the summer of 1903, the coolest in 87 years or more; and the following winter of 1903-04 which was the coldest in a hundred years.

ABSOLUTE EXTREMES OF TEMPERATURE 1871-1903.*

	Absolute Max.	Year.	Day.	Absolute Min.	Year.	Day.	Absolute Range.
December	73°	1889	26	— 3°	1880	30	76°
January	73	1890	13	— 6	1881	1	79
February	78	1874	23	— 7	1899	10	85
March	82	1894	22	5	1873	4	77
April	94	1896	18	24	1875	19	70
May	96	1896	10	34	1876	1	62
June	99	1901	30	47	1891	8	52
July	104	1898	3	55	1891	8	49
August	100	1900	10	51	1890	24	49
September	101	1881	7	39	1888	30	62
October	90	1897	16	30	1876	16	60
November	79	1900	21	15	1880	22	64
Winter	78	1874	Feb. 23	— 7	1899	Feb. 10	85
Spring	96	1896	May 10	5	1873	Mar. 4	91
Summer	104	1898	July 3	47	1891	June 8	57
Autumn	101	1881	Sept. 7	15	1880	Nov. 22	86
Year	104	1898	July 3	— 7	1899	Feb. 10	111

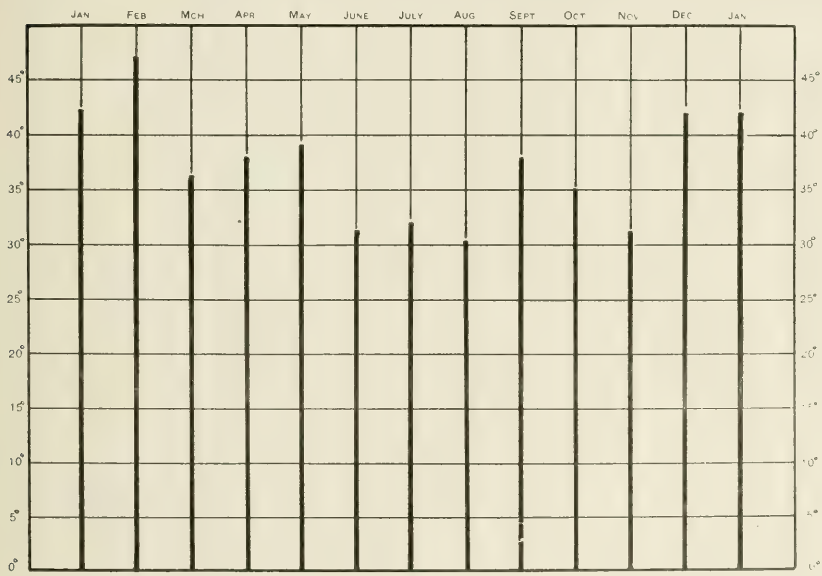


FIG. 24.—Greatest Daily Range of Temperature. (See Table XXI.)

THE GREATEST DAILY RANGE OF TEMPERATURE.

In Table XXI the greatest difference between the daily maximum and minimum temperatures, or the greatest daily range, is entered for each

month and year from 1871 to 1903, together with the daily average range for each ten-year period. There is a marked uniformity in the size of the daily ranges throughout the year, the average monthly values ranging be-

TABLE XXI.—GREATEST DAILY RANGE OF TEMPERATURE.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Extreme
1871	25	19	25	29	20	17	20	18	23	23	20	18	29
1872	13	28	25	25	29	20	20	21	35	24	24	25	35
1873	28	32	36	22	30	31	22	25	38	25	29	22	38
1874	27	27	26	28	31	28	25	28	23	29	30	31	31
1875	32	32	26	30	31	26	28	20	30	28	27	28	32
1876	38	29	33	29	29	28	26	26	26	27	31	34	38
1877	28	33	32	29	25	26	22	23	23	26	26	30	33
1878	24	23	35	24	27	23	22	22	23	25	23	21	35
1879	33	28	27	28	33	30	27	23	23	25	26	24	33
1880	27	24	26	32	30	26	22	22	23	23	25	21	32
1881	32	24	20	34	25	23	25	25	28	24	24	28	34
1882	23	27	27	28	29	25	22	23	21	23	26	31	31
1883	20	29	30	26	32	22	25	25	24	22	24	22	32
1884	30	26	23	26	25	28	25	21	24	28	28	21	30
1885	42	36	22	27	27	27	24	27	25	23	24	31	42
1886	22	40	33	29	30	23	24	21	25	28	28	26	40
1887	25	28	24	38	24	29	32	22	26	28	27	24	38
1888	22	30	29	34	24	28	24	24	22	25	27	24	34
1889	20	25	33	34	30	25	23	24	25	29	27	30	34
1890	26	24	33	33	29	28	24	23	25	21	27	24	33
1891	23	27	26	34	30	26	25	24	26	32	31	26	34
1892	26	31	36	28	30	27	23	22	30	33	25	22	36
1893	24	26	32	35	30	26	30	25	28	32	26	31	35
1894	22	28	35	29	30	29	28	26	27	30	26	25	35
1895	22	29	29	30	31	27	23	28	25	35	27	22	35
1896	25	31	34	32	39	24	27	27	34	27	30	26	39
1897	19	22	30	38	31	25	23	26	31	30	31	23	38
1898	25	27	29	29	30	30	28	26	29	28	26	42	42
1899	27	25	30	32	28	27	28	28	29	26	24	26	32
1900	26	47	30	31	35	31	27	30	27	31	29	29	47
1901	27	23	34	34	30	29	27	22	23	35	31	39	39
1902	22	19	26	33	33	29	30	26	26	27	28	23	33
1903	25	28	31	40	29	26	26	26	30	30	28	28	40
1904	26	20	32	30	32	27	27	29	....	....	....	...	....
Means.													
1871-1880	27.5	27.5	29.1	27.6	28.5	25.5	23.4	22.8	26.7	25.5	26.1	25.4	33.6
1881-1890	26.2	28.9	27.4	30.9	27.5	25.8	24.8	23.5	24.5	25.1	26.2	26.1	34.8
1891-1900	23.9	29.3	31.1	31.8	31.4	27.2	26.2	26.2	28.6	30.4	27.5	27.2	37.3
1871-1902	25.8	28.1	29.2	30.3	29.3	26.3	25.0	24.2	26.5	27.2	26.8	26.5	35.3

Table XXI shows the greatest daily range of temperature (the greatest difference between the maximum and minimum of any day) for each month and year from 1871 to 1904. Also the average of the greatest daily ranges for the entire period of 32 years and for each 10-year period.

tween 30.3° for April and 24.2° for August. The extreme daily ranges for each month and for the year are shown in the following tabular statement and in Fig. 24.

EXTREME DAILY RANGE OF TEMPERATURE.

1871-1903.	Day.	Year.	Range.	Max.	Min.
January	17	1885	42°	65	23
February	24	1900	47°	55	8
March	7	1873	36°	50	14
April	4	1903	40°	71	31
May	9	1896	39°	93	54
June	11	1900	31°	92	61
July	18	1887	32°	102	70
August	6	1900	30°	97	67
September	16	1873	38°	79	41
October	19	1901	35°	75	40
November	13	1876	31°	68	37
December	31	1898	42°	59	17
Year	Feb.	1900	47°	55	8

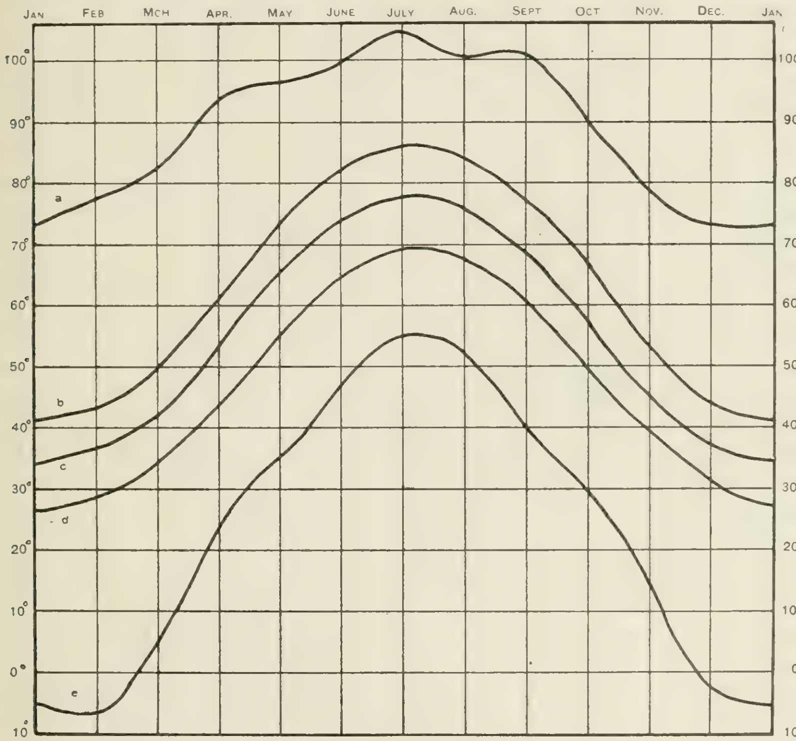


FIG. 25.—(*a*) Extreme Monthly Maximum Temperature.
(*b*) Mean " " "
(*c*) Average " Temperature.
(*d*) Mean " Minimum "
(*e*) Extreme " " "

(See Tables XXII, XXIII and XXIV.)

TABLE XXII.—MONTHLY MAXIMUM TEMPERATURES.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Extreme
1871	63	66	71	85	90	91	92	91	81	78	69	53	92
1872	56	61	65	88	89	94	97	96	94	80	63	55	97
1873	58	62	68	75	89	95	96	94	93	73	64	66	96
1874	69	78	72	68	89	98	96	97	90	78	71	67	98
1875	52	59	63	74	88	97	96	88	92	77	66	67	97
1876	71	65	69	75	88	95	99	90	88	77	76	56	99
1877	54	63	65	80	92	95	93	94	88	80	68	67	95
1878	57	63	72	79	85	92	98	92	87	80	61	61	98
1879	64	58	71	83	94	94	99	92	85	89	78	63	99
1880	65	67	76	80	93	95	99	91	91	81	69	56	99
1881	45	64	59	84	95	92	96	98	101	89	71	71	101
1882	59	59	69	82	83	97	93	90	88	78	73	51	97
1883	50	64	65	74	86	90	96	92	81	82	71	60	96
1884	52	68	64	80	89	93	95	94	93	89	71	66	95
1885	65	50	68	82	82	95	99	94	86	76	74	64	99
1886	57	67	71	88	88	89	92	92	91	82	73	52	92
1887	65	72	57	85	87	94	102	91	88	85	69	59	102
1888	50	60	74	90	86	94	94	96	84	74	74	58	96
1889	60	48	68	80	93	91	93	90	84	82	70	73	93
1890	73	74	77	83	87	93	98	95	87	78	73	59	98
1891	60	73	60	86	88	94	89	94	90	85	64	67	94
1892	58	57	65	83	87	94	99	95	88	83	70	64	99
1893	52	61	62	81	89	98	96	90	88	84	62	67	98
1894	57	59	82	79	87	98	97	93	94	85	70	59	98
1895	60	62	72	86	95	97	95	96	96	74	77	61	97
1896	59	61	69	94	96	93	96	98	94	77	75	66	98
1897	60	56	72	84	84	95	94	90	97	90	75	66	97
1898	60	65	77	81	92	98	104	95	97	84	67	66	104
1899	59	60	74	80	90	98	96	97	94	78	72	67	98
1900	62	65	67	84	94	93	100	100	95	85	79	62	100
1901	64	49	74	86	83	99	103	93	92	81	65	65	103
1902	48	59	77	89	90	94	99	91	92	80	76	59	99
1903	57	71	72	91	92	88	96	97	89	83	75	52	97
1904	58	64	70	80	89	95	77	89	....	....	....	....	...
Means.													
1871-1880	60.9	64.2	69.2	78.7	89.7	94.6	96.5	92.5	88.9	79.3	68.5	61.1	97.0
1881-1890	57.6	62.6	67.2	82.8	87.6	92.8	95.8	93.2	88.3	81.5	71.9	61.3	96.9
1891-1900	58.7	61.9	70.0	83.8	90.2	95.8	96.6	94.8	93.3	82.5	71.1	64.5	98.3
1871-1902	58.9	62.3	69.2	82.1	89.0	94.5	96.6	93.4	90.3	81.1	70.5	62.3	97.6

Table XXII contains the highest recorded temperature during each month and year from 1871 to 1904, together with the average of the monthly extremes for the entire period of 32 years and for each 10-year period. The observations were obtained by means of a self-registering mercurial thermometer, excepting for the time from January, 1871, to July, 1872, during which period the 3 p. m. observations were employed.

Monthly and Annual Extremes.

The highest and lowest temperatures recorded during each month and year from 1871 to 1903 are shown in Tables XXII and XXIII, together with the average values for each ten-year period and for the entire period.

The absolute monthly extremes of temperature, the average maximum, and minimum, and the monthly normals are shown in Fig. 25. Fig. 26 shows the absolute annual extremes and the mean annual temperature for each year from 1871 to 1903.

TABLE XXIII.—MONTHLY MINIMUM TEMPERATURES.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Extreme
1871	14	10	36	42	51	62	60	63	45	40	28	5	5
1872	11	15	9	38	48	58	68	62	50	38	17	6	6
1873	—4	2	5	38	44	49	62	57	40	30	22	22	—4
1874	13	15	23	27	41	54	62	52	53	35	24	21	13
1875	—2	4	19	24	42	54	62	58	43	34	16	12	—2
1876	17	12	12	30	34	51	59	55	45	30	25	1	1
1877	1	18	9	32	41	55	64	63	48	41	25	22	1
1878	6	20	21	42	43	51	65	59	47	35	33	15	6
1879	0	12	24	29	43	52	60	56	40	30	20	13	0
1880	17	15	22	30	38	52	62	61	50	35	15	—3	—3
1881	—6	4	27	25	46	55	65	60	59	39	24	24	—6
1882	7	23	26	29	38	53	59	57	48	44	26	10	7
1883	11	22	16	30	45	55	62	59	46	40	23	17	11
1884	8	10	14	34	45	52	60	59	49	35	26	9	8
1885	10	3	12	32	44	56	56	53	46	38	32	15	3
1886	2	—1	15	34	45	52	59	58	50	36	26	15	—1
1887	7	21	21	30	51	52	67	55	42	32	25	16	7
1888	9	11	12	33	41	52	57	55	39	36	25	16	9
1889	20	3	28	34	43	52	61	58	46	34	28	23	3
1890	20	23	12	31	43	55	55	51	46	36	26	18	12
1891	21	16	16	30	40	47	55	54	51	33	18	17	16
1892	12	14	20	32	46	54	58	60	49	34	21	14	12
1893	1	11	16	36	45	57	58	57	44	31	22	18	1
1894	18	8	20	30	43	47	56	57	45	36	24	7	7
1895	9	1	21	34	40	53	55	57	46	34	26	14	1
1896	9	5	16	31	47	54	61	54	46	36	29	14	5
1897	8	18	28	29	44	48	62	60	45	38	27	16	8
1898	17	10	27	26	40	55	57	59	52	34	24	14	10
1899	6	—7	26	29	47	55	59	58	42	34	31	9	—7
1900	10	8	12	30	40	55	58	61	50	36	28	15	8
1901	14	14	13	37	47	52	64	61	46	37	24	11	11
1902	17	13	20	35	43	53	62	55	48	34	32	18	13
1903	12	5	29	27	37	53	59	58	43	35	18	11	5
1904	2	5	20	27	43	50	57	55	....	....	....	....	....
Means.													
1871-1880	7.3	12.3	18.0	33.2	42.5	53.8	62.4	58.6	46.1	34.8	22.5	11.4	2.3
1881-1890	8.8	11.9	18.3	31.2	44.1	53.4	60.1	56.5	47.1	37.0	26.1	16.3	5.3
1891-1900	11.1	8.4	20.2	30.7	43.2	52.5	57.9	57.7	47.0	34.6	25.0	13.8	6.1
1871-1902	9.5	11.0	18.7	32.0	43.4	53.2	60.3	57.6	46.8	35.5	24.8	13.9	5.0

Table XXIII contains the lowest recorded temperature during each month and year from 1871 to 1904, together with the average of the monthly extremes for the entire period of 32 years and for each 10-year period. The observations were obtained by means of a self-registering alcohol minimum thermometer, excepting for the time from January, 1871, to July, 1872, during which period the 7 a. m. observations were employed.

The absolute range of temperature at Baltimore, the difference between the highest (104°), and lowest (7° below zero) recorded readings of the thermometer, is 111°. The former occurred on July 3, 1898, and the latter on February 10, 1899. On both of these days records for extreme heat and cold were broken in many parts of the country.

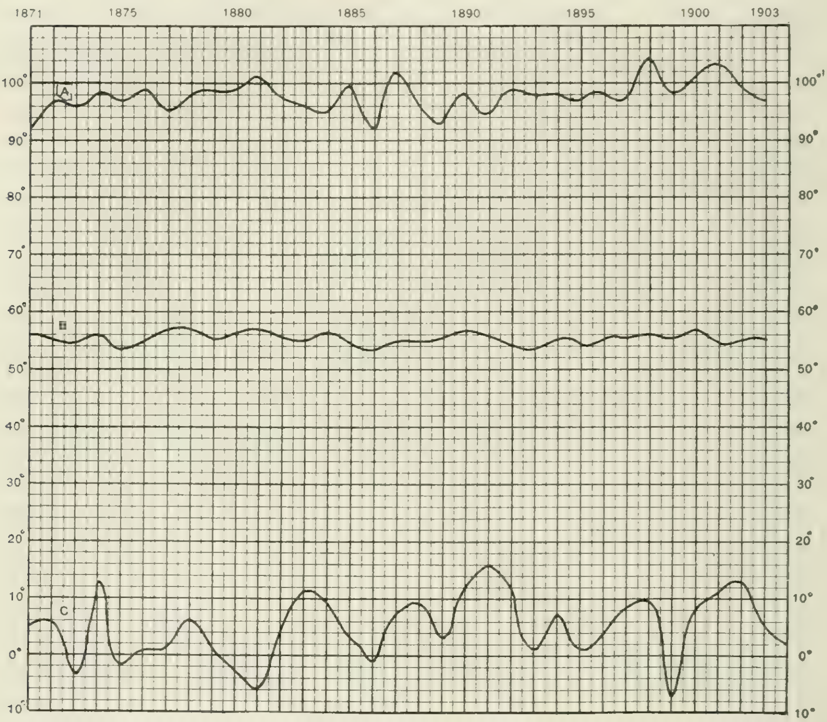


Fig. 26.—(*A*) Absolute Annual Maximum Temperature.
(*B*) Average " Temperature.
(*C*) Absolute " Minimum Temperature.
(See Tables XXII, XXIII and XXIV.)

The Greatest Monthly Range.

The difference between the highest and lowest temperatures recorded during each month of the year is entered in Table XXIV for every year from 1871 to 1903. The extreme difference for each month during the entire period is shown in the table which follows, together with the ex-

tremes of temperature and the year of occurrence. The extreme range is also shown in Fig. 27.

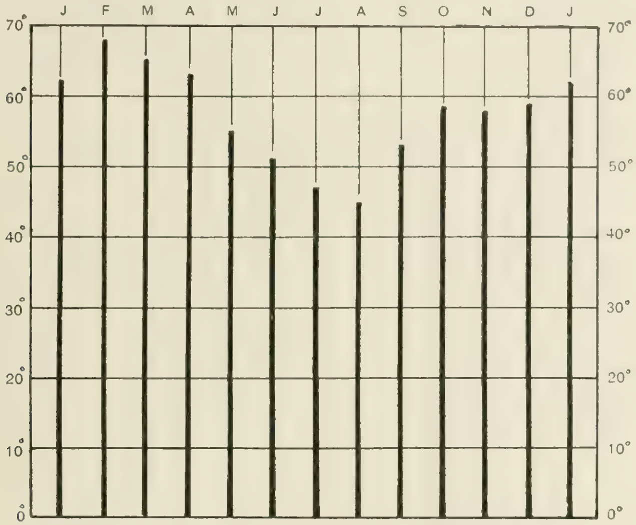


Fig. 27.—Greatest Monthly Range of Temperature. (See Table XXIV.)

EXTREME MONTHLY RANGE OF TEMPERATURE.

1871-1903.	Year.	Range.	Max.	Min.
January	1873	62°	58	— 4
February	1886	68°	67	— 1
March	1890	65°	77	12
April	1903	64°	91	27
May	1895	55°	95	40
June	1894	51°	98	47
July	1898	47°	104	57
August	1874	45°	97	52
September	1873	53°	93	40
October	1879	59°	89	30
November	1879	58°	78	20
December	1880	59°	56	— 3

Frequency of Days with Frost.

As the frequency of occurrence of days with a temperature of freezing, and the distribution of such days especially in the autumn and spring seasons, is a matter of greatest practical importance in agricultural and commercial affairs, the subject is here given more than ordinary attention and space. For purposes of convenience all days during which a minimum temperature of 32° was recorded are classed as frost days. It is a well recog-

nized fact of observation, however, that frost usually occurs before the temperature falls to the freezing point (32°) as officially recorded. The apparent inconsistency is of course explained by the method of exposure of

TABLE XXIV.—ABSOLUTE MONTHLY RANGE OF TEMPERATURE.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Extreme
1871	49	56	35	43	39	29	32	28	36	38	41	48	56
1872	45	46	56	50	41	42	29	41	44	42	47	47	56
1873	62	53	63	37	45	46	34	37	53	44	42	52	63
1874	56	63	49	41	48	44	34	45	39	43	47	50	63
1875	54	53	44	50	46	43	34	30	49	43	50	55	55
1876	54	53	57	45	54	44	40	35	43	47	51	55	57
1877	53	45	56	48	51	40	29	31	40	39	43	45	56
1878	52	43	51	37	42	41	33	33	40	45	28	46	52
1879	61	46	47	54	51	42	39	36	45	59	58	50	61
1880	37	52	54	50	55	43	37	30	41	46	47	59	59
1881	51	60	32	59	49	37	31	38	42	50	47	47	60
1882	52	36	43	53	45	44	39	33	40	34	47	41	53
1883	39	60	49	44	41	35	34	33	35	38	48	43	60
1884	44	58	50	46	44	41	35	35	44	54	45	57	58
1885	55	47	56	50	38	39	43	41	40	38	42	49	56
1886	55	68	56	54	43	37	33	34	41	46	47	37	68
1887	58	51	36	55	36	42	35	36	46	53	44	43	58
1888	40	49	62	57	46	42	38	41	45	38	49	42	62
1889	40	45	40	46	50	39	32	32	38	48	42	50	50
1890	53	51	65	52	44	38	43	44	41	42	47	41	65
1891	39	57	44	56	48	47	34	40	39	52	46	50	57
1892	46	46	45	51	41	40	41	35	39	49	49	50	51
1893	51	50	46	45	44	41	38	33	44	53	40	49	53
1894	39	51	62	49	44	51	41	36	49	49	46	52	62
1895	51	61	51	52	55	44	40	39	50	40	51	47	61
1896	50	56	53	63	49	39	35	44	48	41	46	52	63
1897	52	38	44	55	40	47	32	30	52	52	48	50	55
1898	43	55	50	55	52	43	47	36	45	50	43	52	55
1899	53	67	48	51	43	43	37	39	52	44	41	58	67
1900	52	57	55	54	54	38	42	39	45	49	51	47	57
1901	50	35	61	49	36	47	39	32	46	44	41	54	61
1902	31	46	57	54	47	41	37	36	44	46	44	41	57
1903	45	66	43	64	55	35	37	39	46	48	57	41	66
1904	56	59	50	53	46	45	40	34	....	....	...	....	....
Means.													
1871-1880	52.3	51.0	51.2	45.5	47.2	41.4	34.1	34.6	43.0	44.6	45.4	50.7	57.8
1881-1890	48.7	52.5	48.9	51.6	43.6	39.4	36.3	36.7	41.2	44.1	45.8	45.0	59.0
1891-1900	47.6	53.8	49.8	53.1	47.0	43.3	38.7	37.1	46.3	47.9	46.1	50.7	58.1
1871-1902	49.0	51.7	50.5	50.2	45.7	41.5	36.5	36.0	43.6	45.5	45.6	48.7	58.3

Table XXIV shows the greatest monthly range of temperature (the difference between the highest and lowest temperature recorded within the month) for each month and year from 1871 to 1904, also the average value of these monthly ranges for a period of 32 years, and for each 10-year period.

the thermometer. Usually thermometers are placed in a "shelter" which shields the instrument from undue radiation from the ground; the shelter

is also usually mounted at a considerable distance above the ground, varying from four or five feet to a hundred feet or more. In a quiet atmosphere with a clear sky, radiation from the ground is very rapid during the night and early morning hours. The temperature at the surface of the earth may fall considerably below that of the air but a few feet above

TABLE XXV.—NUMBER OF DAYS WITH A MINIMUM TEMPERATURE OF 32° OR BELOW.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Season
1871-2	..	3	18	19	17	16	..	73
1872-3	..	9	26	21	18	20	..	94
1873-4	2	13	12	14	19	10	5	75
1874-5	..	8	20	29	24	18	5	104
1875-6	..	8	15	17	19	17	1	77
1876-7	1	5	30	29	19	17	1	102
1877-8	..	2	9	19	14	4	..	48
1878-9	..	..	20	27	25	10	3	85
1879-80	1	10	14	9	17	11	2	64
1880-1	..	12	24	26	20	8	6	96
1881-2	..	3	9	19	12	6	2	51
1882-3	..	7	15	25	18	19	1	85
1883-4	..	7	15	24	11	8	..	65
1884-5	..	4	11	20	24	17	2	78
1885-6	..	1	17	24	22	11	..	75
1886-7	..	6	25	24	15	20	4	94
1887-8	1	5	19	29	19	19	..	92
1888-9	..	7	16	16	24	7	..	70
1889-90	..	4	8	10	10	15	2	49
1890-1	..	4	21	18	11	16	2	72
1891-2	..	6	10	23	13	15	1	68
1892-3	..	8	17	28	20	14	..	87
1893-4	1	9	20	17	18	7	3	75
1894-5	..	6	15	26	26	14	..	87
1895-6	..	5	14	22	21	21	3	86
1896-7	..	3	20	22	16	6	1	68
1897-8	..	5	13	15	19	4	5	61
1898-9	..	5	22	21	21	8	3	80
1899-1900	..	4	19	20	17	16	2	78
1900-1	..	4	19	23	28	7	..	81
1901-2	..	11	19	27	23	7	..	87
1902-3	..	1	22	21	16	2	2	64
1903-4	..	16	25	29	24	15	5	114
Means.								
1872-1881	0.4	7.0	18.8	21.0	19.2	13.1	2.3	81.8
1882-1891	0.1	4.8	15.6	20.9	16.6	13.8	1.3	73.1
1892-1901	0.1	5.5	16.9	21.7	19.9	11.2	1.8	77.1
1872-1903	0.2	6.1	17.5	21.6	18.8	12.3	1.9	78.4

under such conditions. Thus we may have frost, especially in the low places, when the thermometer records a minimum temperature of 35° or 40°, according to the position of the instrument. In view of these facts the figures entered in the following tables to represent the frequency of frost days must be regarded as the lower limit of frequency; the

figures would be increased to a small extent by placing the thermometer nearer the ground. To enumerate frost days upon the basis of the actual observation of frost on the ground, introduces additional difficulties as the production of frost depends not only on a temperature of 32° or

TABLE XXVI.—LONGEST PERIOD OF CONSECUTIVE DAYS WITH A MINIMUM TEMPERATURE OF 32° OR BELOW.

	No. of Days.	Time of Occurrence.
1871-2	15	Jan. 22-Feb. 5
1872-3	23	Dec. 9-Dec. 31
1873-4	14	Jan. 30-Feb. 12
1874-5	30	Dec. 30-Jan. 28
1875-6	9	Dec. 13-Dec. 21 Jan. 30-Feb. 7
1876-7	35	Dec. 15-Jan. 18
1877-8	11	Jan. 28-Feb. 7
1878-9	40	Dec. 16-Jan. 24
1879-80	11	Feb. 1-Feb. 11
1880-1	17	Jan. 23-Feb. 8
1881-2	9	Dec. 30-Jan. 7
1882-3	16	Jan. 2-Jan. 17
1883-4	9	Jan. 2-Jan. 10
1884-5	18	Jan. 10-Jan. 27
1885-6	21	Jan. 6-Jan. 26
1886-7	27	Dec. 25-Jan. 20
1887-8	27	Jan. 9-Feb. 4
1888-9	9	Feb. 19-Feb. 27
1889-90	10	Mar. 1-Mar. 10
1890-1	9	Feb. 27-Mar. 7
1891-2	12	Mar. 11-Mar. 22
1892-3	24	Jan. 3-Jan. 26
1893-4	9	Dec. 1-Dec. 9
1894-5	34	Jan. 23-Feb. 25
1895-6	15	Feb. 9-Feb. 23
1896-7	15	Jan. 23-Feb. 6
1897-8	15	Jan. 27-Feb. 10
1898-9	24	Jan. 25-Feb. 17
1899-1900	12	Dec. 25-Jan. 5
1900-1	38	Jan. 23-Mar. 1
1901-2	27	Jan. 26-Feb. 21
1902-3	12	Feb. 16-Feb. 27
1903-4	27	Dec. 26-Jan. 21
Means.		
1872-1881	20	
1882-1891	16	
1892-1901	20	
1872-1904	19	

under at the place of formation, but also upon the relative amount of moisture in the atmosphere. The actual observation of frost has, however, been employed in the table in which first and last frosts of the autumn and spring respectively are recorded and a minimum temperature of 32° resorted to only in case of conditions unfavorable to the occurrence of frosts on account of a dry atmosphere.

In making a comparison of the relative severity of winter seasons the frequency of occurrence of a minimum temperature of 32° or under is in some .respects a more satisfactory test of the general character of the season than the usual one of the average temperature.

In Table XXV, the frequency of occurrence of such days is shown for each month from October to May, and the total number for each year from 1871 to 1904. The season having the greatest number of frost days from 1871 to 1904, is that of 1903-04 when 114 were recorded. There were 104 in 1874-75, and 102 in 1876-77. In 1877-78 there were but 48; in 1889-90, 49. The average number for the entire period of 33 years is 78.

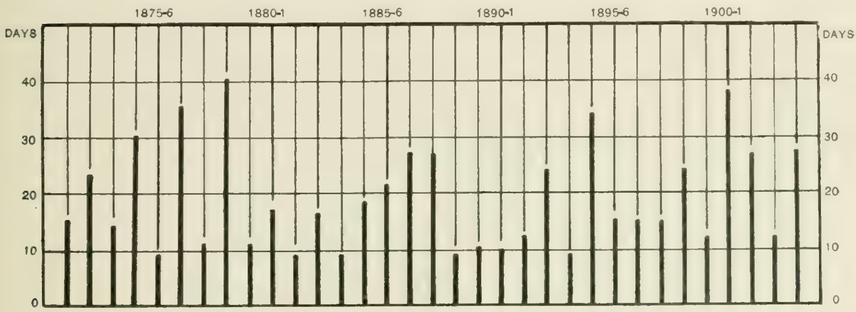


FIG. 28.—Longest Period of Consecutive Days with a Minimum Temperature of 32° or Below. (See Table XXVI.)

In Table XXVI the longest period of consecutive days with a minimum temperature of 32° is recorded for each year, with the time of occurrence; the duration of these periods is also presented graphically in Fig 28. The cold periods of this class begin most frequently in the month of January, though many begin in December. In one instance the longest uninterrupted cold spell fell entirely within the month of March, namely in 1890, from March 1-10.

The season credited with the longest period of consecutive days with a minimum of 32° is that of 1878-79 when the minimum was 32° or below daily without interruption from December 16 to January 24, or 40 days. In the winters of 1875-76, 1881-82, 1883-84, 1888-89, 1890-91 and 1893-94, the longest period was 9 days. The average length of uninterrupted periods of freezing weather is 19 days.

The cold days occurring in Baltimore from 1871 to 1904 were also tabulated on the basis of a daily mean temperature below 32° and below 14°. The results are shown in Fig. 29 for the entire season. The average winter season contains 33 days with a mean temperature below freezing point. The winter season of 1903-04 contained 66, the highest number recorded during any year of the period; the seasons of 1884-85 and 1901-02 follow with 50 each. In 1877-78 there were but 17; in 1879-80

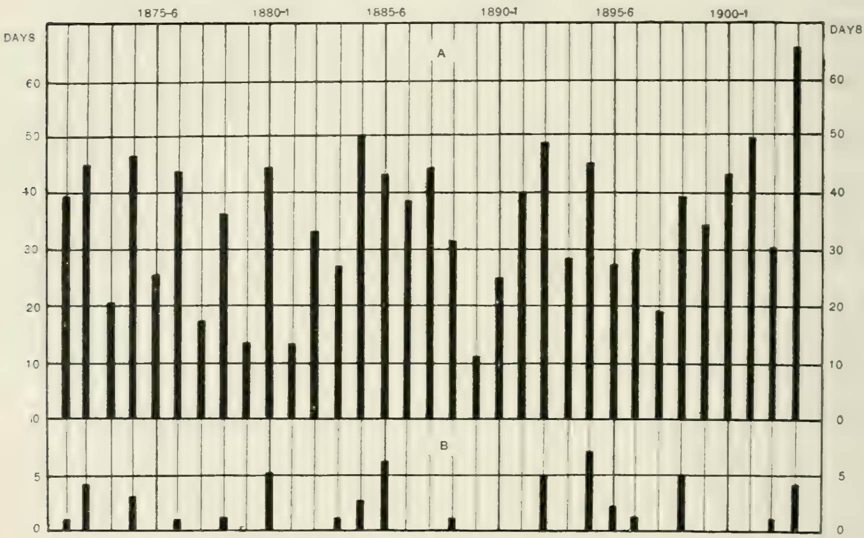


FIG. 29.—(*A*) Number of Days with Mean Temperature below 32°
(*B*) " " " " " 14°

and 1881-82, 13; and in the winter of 1889-90, but 10, the lowest number on record. The average number for each 10-year period from 1871-1904 is shown in the following table:

AVERAGE NUMBER OF DAYS WITH A MEAN TEMPERATURE BELOW 32°

Decade.	Nov.	Dec.	Jan.	Feb.	March.	April.	Season.
1871-1880	0.8	8.4	9.8	8.8	2.9	0.1	30.8
1881-1890	1.3	6.9	12.5	7.8	4.8	0.0	83.3
1891-1900	1.3	7.6	11.8	9.1	3.7	0.0	33.5
1871-1904	1.3	8.0	11.9	9.5	3.6	0.0	34.3
Greatest number (1903-4)	6	15	23	20	2	0	66
Least number (1889-90)	0	1	2	1	6	0	10

The frequency of days during which the highest temperature of the day fell below the freezing point is shown in Fig. 30. The average monthly and annual frequency for the entire period of 33 years and for each decade is given below.

AVERAGE FREQUENCY OF DAYS WITH A MAXIMUM TEMPERATURE BELOW 32°

Decade.	Nov.	Dec.	Jan.	Feb.	March.	Season.
1871-1880	0.3	3.7	4.7	2.2	0.8	12.0
1881-1890	0.3	2.2	6.7	2.8	1.6	13.6
1891-1900	0.1	3.5	6.3	5.9	0.9	16.7
1871-1904	0.2	3.6	6.0	4.3	1.0	15.1
Greatest number (1892-3)	0	10	19	6	1	36
Least number (1877-8)	0	0	3	0	0	3

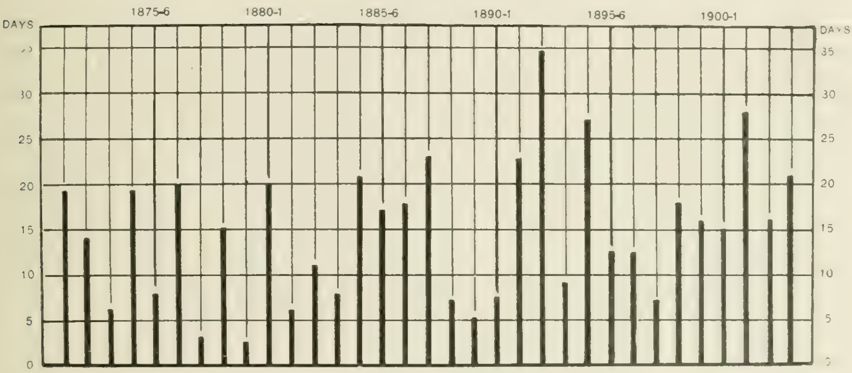


FIG. 30.—Annual Frequency of Days with a Maximum Temperature below 32°.

With an average annual frequency of 15 days, the number varied from 3 in 1877-78 to 36 in 1892-93. The winter of 1903-04 contained 21.

In Fig. 31, the annual frequency of cold days is shown on a basis of the occurrence of a daily minimum temperature of 20° in the months of December, January and February and a minimum of 28° in November, March, and April. In the table below the average monthly and seasonal frequency of occurrence of such days is indicated for each ten-year period from 1871 to 1904, and for the entire period of 33 years.

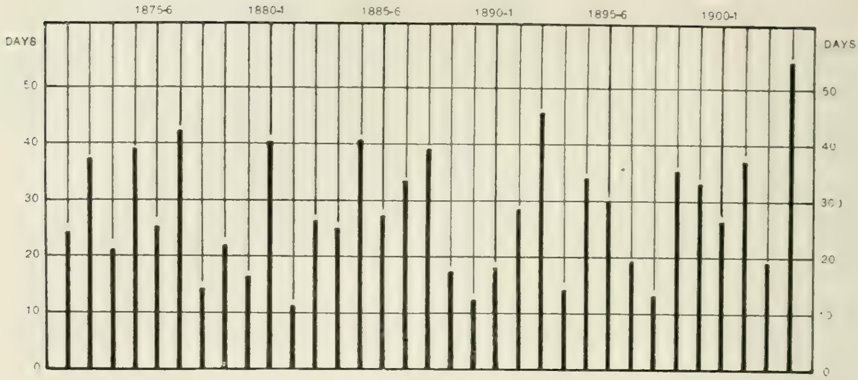


FIG. 31.—Annual Frequency of Cold Days.

20° or less in December, January and February.
28° " " November, March and April.

(See Tables XXVII and XXVIII.)

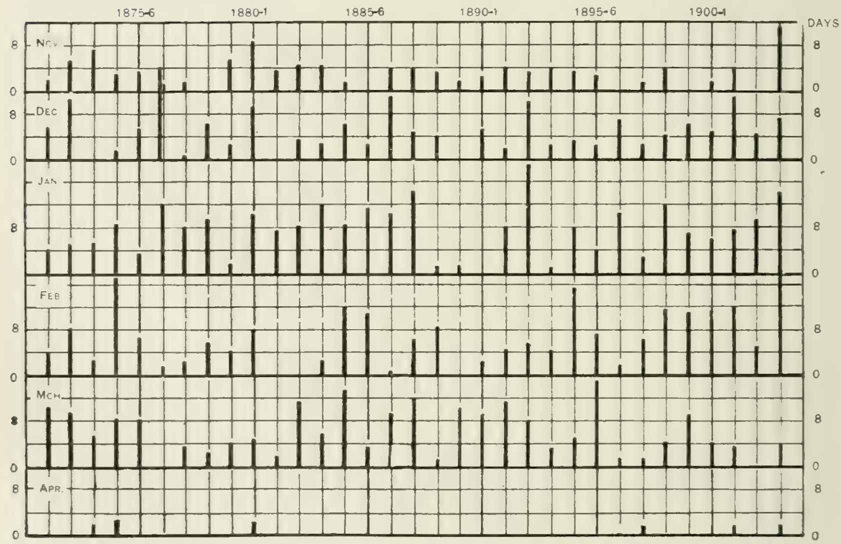


FIG. 32.—Monthly Frequency of Cold Days.

(a) 20° or less in December, January and February.
(b) 28° " " November, March and April.

(See Tables XXVII and XXVIII.)

FREQUENCY OF DAYS WITH A MINIMUM TEMPERATURE OF 20° IN WINTER AND 28° IN SPRING AND AUTUMN.

Decade.	Nov.	Dec.	Jan.	Feb.	March.	April.	Season.
1871-1880	2.8	5.0	6.0	5.2	6.1	0.5	24.8
1881-1890	3.0	4.1	8.2	4.7	6.9	0.1	27.0
1891-1900	2.3	4.2	7.1	6.6	6.6	0.1	26.9
1871-1904	2.8	4.6	7.3	6.2	6.0	0.2	27.1
Greatest number (1903-4)	11	7	14	18	4	1	55
Least number (1881-2)	3	0	7	0	1	0	11

TABLE XXVII.—LIST OF COLD DAYS.—JANUARY.
(Minimum of 20° or below.)
DAY OF MONTH.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	
1871									19	17													14	17		15						5
2															20														14	18	11	4
3											14														19				6	—4	8	5
4															14	13	13	14								18						5
5	15					18			6	—2	2				16				20	14												8
6											17		19	20																		3
7	10	13	8	6	1	10			11	13	17													19	13	16						12
8			18		20	15	11	6																18					19	19		8
9		6	0	5	6	14	14			20										18	18											9
1880														17																		1
1	—6	16	9									20		20	12					20							17	15	20			10
2		19	18	17	19																		17	7	17							7
3										17	17	13	17		18							19	11	13								8
4					12	8	9	20		20						17	16			20	14	18			20	16						12
5			18															20				10	15				20	14	11	18		8
6									11	7	6	4	2	6	9	20							17	12	18							11
7		12	7	13			20	13	14	15	12							12	9													10
8											17	14				20	20		19	16	16	9	14		15	20	13	10	11			14
9																				20												1
1890																						20										1
1																																0
2								19								19	12			13	14	19				19	14					8
3				15	17	14	19	19	16	6	5	13	9	7	8	1	12	2	16	15	13	8										19
4																										18						1
5	17	19			14								9	12											17				19		20	8
6				11	9	9	18																									4
7													20							20				16	8	8	16	13	14	15	17	10
8		18																												19		2
9	9	6	16							16	10	9							20	20							20	18	20		20	12
1900	15	14																								19	19		15	12	10	7
1			20	18		20													16	14											19	6
2				19	18	20																						20	17	19	20	7
3									17	18		13	12	18				20	17	19				20								9
4		17	8	8	2	5				19							20	11	6	15							18	17		18	20	14
																																249

Table XXVII contains a complete list of all days from 1871 to 1904 during which the temperature fell to 28° or lower in November, March and April, and to 20° in December, January and February; together with the minimum temperature recorded on the corresponding days, and the number of such days in each month. Fig. 31 shows the annual frequency of cold days, and Fig. 32 the monthly frequency.

Cold days of the class described in the above table occur most frequently in the month of January, as is the case with the other classes tabulated. A peculiarity in the seasonal distribution is however revealed

TABLE XXVII.—LIST OF COLD DAYS.—FEBRUARY.

(Minimum of 20° or below.)

DAY OF THE MONTH.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	Total
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	
1871					16	10									17															3
2	17	17												15	15															4
3	16	18	16						19	18													12	2	20					8
4		20							15																					2
5	20			19	15	20	12	10	6	4	14	18		20	10	6	12	9	16									18		17
6		16	13		16	18																	13	12						6
7														18																1
8			20	20																										2
9														20	12	20					19							17		5
1880		15			19					17										20										4
1	15	4	7	12	14	18	15																	14						8
2																														0
3																														0
4																												16	10	2
5		18					20			13	3	14					10	20	14	10	8	14	15							12
6	18		13	8	−1	7		19												19	20					19	17	18		11
7																														0
8										12	15				20	1											19	13		6
9						18	17	18					13										12	3	14	20				8
1890																														0
1				20	16																									2
2						15						20	14				18													4
3					16												20	19		11	12									5
4					14														17					13	8					4
5	17		7	16	9	1	6	2	4	12	14	16	20	15	18									20						15
6																19	5	8	19	8	11	13								7
7	18																													1
8	14	10	12	11												20	19													6
9	8	14						8	2	−7	−6	5	6	6	6	15														11
1900	8	8															20	13	14	18				8	8	15	9	18		11
1	14	19			19	18	16					19	16	14									16	16	19					11
2			15	15	13	14		14	19	19	19		18	16					18	18										12
3																	12	7	5	12	19									5
4	12	11	16	17	19				18	14	20	18	14		18	17	5	13		16	19				19	16				18
																														211

in the comparatively high frequency of occurrence of such days in March, after making due allowance for the fact that the March minimum is 8° higher than the minimum for the winter months.

The distribution of cold days of this class by months and years is shown in Fig. 32; a complete list with temperatures recorded is contained in Table XXVII.

TABLE XXVII.—LIST OF COLD DAYS.—March.

(Minimum of 28° or below.)

DAY OF MONTH.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	
1871																																0
2	27	24	24	18	9	18	23									27				19	21											10
3	22	27	12	5	10	13	14																				23	28				9
4												28	23	25										23	28							5
5	20			27	26												25	23			26	19	21									8
6			20	27										26				18	12	24	26	25										8
7					28	26			25	17	21				24	27	20	9	15	12	27											12
8																								26	21	21						3
9	24			26																												2
1880												28	24												22	28						4
1	27	27			28	28																										4
2																									26							1
3				28	19	27	22	16	23			28				23					22	24		23								11
4	14	24	23	18	23																											5
5								25	21		25		25	26			17	19	20	12	12	19	18	19								13
6	19	15	23																													3
7	26			27	25										24		27	26						28					23	21		9
8				24	20	15	20					18	12	14				24			21	16	24	27								12
9																														28		1
1890		24	19	27		22	12	21	22	27						23	28															10
1	20	16	24		24	22	27							27	21		24															9
2			28								20	25		24	25	23	24	24	23		21	23										11
3				24	16	24									28	18	27	25											24			8
4																										27	20	24				3
5					21										25	28	25					27										5
6			24	23	24							20	16	18	25		27	27		26	23		26	18	25		27					15
7																	28															1
8	27																															1
9							27	25	28												26											4
1900											22	12	26		21	22	15	14			28	26										9
1	28				19	13	14																									4
2						26												22	20													3
3																																0
4				24	20												28												28			4
																																207

TABLE XXVII.—LIST OF COLD DAYS.—April.

(Minimum of 28° or below.)

DAY OF THE MONTH.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	
1874					28							27																			2
1875																	27	26	24												3
1881					25																										1
1898						26																									1
1903					27																										1
1904																				27											1
																															9

The Frequency of Cold Waves.

A cold wave, to come within the definition of the U. S. Weather Bureau, is a fall in temperature, in the horizon of Baltimore, of 20° within twenty-four hours, to a minimum of 20° in December, January,

TABLE XXVII.—LIST OF COLD DAYS.—November.

(Minimum of 28° or below.)

DAY OF THE MONTH.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	
1871																													28		1
2																	28		28		26								20	17	5
3													28	26	28					24	22		28							25	7
4														27																24	2
5																		27											23	16	3
6																														25	1
7																														25	1
8																															0
9				28	25															23	21	20									5
1880																			23		28	15	16	17		25	22	28			8
1																								28	24	28					3
2																					28							27	26	28	4
3															28	23	25	28													4
4																									26						1
5																															0
6								28																		28	26				3
7																					25								25	27	3
8																					26	25	25								3
9																														28	1
1890																												26	27		2
1																		22	21										24	18	4
2																							26	21	28						3
3																					28				25	22	24				4
4												27								26									24		3
5																					26	28									2
6																															0
7																														27	1
8																									26	26	24	27			4
9																															0
1900																28															1
1																				27		28						25	24		4
2																															0
3							28											26	24	25	25				26	21	18	20	24	25	11
																															94

and February, and to a minimum of 28° in March and November. The designated minimum must be reached not later than 12 hours after the expiration of the 24-hour period. Thus three events are essential for the technical verification of a cold wave, namely: (a) a fall of 20°; (b) the fall must occur within a period of 24 hours; (c) a designated minimum temperature must be reached within 36 hours. Cold waves

fulfilling all these conditions are not of frequent occurrence within the geographical horizon of Baltimore. It has been shown in the paragraphs dealing with diurnal variability of temperature to what extent the frequency of occurrence of given changes in temperature from day

TABLE XXVII.—LIST OF COLD DAYS.—DECEMBER.

(Minimum of 20° or below.)

DAY OF THE MONTH.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	
1871					12	17														7	5	16										5
2	17									18	20											6	17	8	8	14	14	13				10
3																																0
4															17																	1
5	16																16	12	16	12												5
6	18	20							4	1	18					13	8	15	10	12	14	15		20	18			18			17	16
7																																0
8																							18	17	15	16		20	16			6
9																										18	13					2
1880							20	18	15	14	13																	14	4	−3	−1	9
1																																0
2							15	10	17																							3
3																							18	17								2
4																		16	10	9	16					20	19					6
5							15	15																								2
6		17	16	18	16			20							18	15	16				20						20			20		11
7	18																												16	17	20	4
8															19					20	20	16										4
9																																0
1890								20																		20			18	19	20	5
1																		17														1
2																					20		18	15	14	14	14	18	15	18	17	10
3						18								20																		2
4																												14	7	16		3
5													14	18																		2
6				19																			20	14	18	20		15	20			7
7																								16	16							2
8													18	14	18																17	4
9																										20	18	18	16	11	9	6
1900														19	15	19	19															4
1					20	16	18								19	17	18	20	17	16	14	11										11
2																									19	18	20	18				4
3																19	20		18							12	11	19	19			7
																																154

to day depends upon the method of determining the change. Basing the 20° fall upon the minimum temperatures, the 8 a. m. or 8 p. m. temperatures from day to day, the Baltimore records from 1871 to 1904 show a frequency of cold waves indicated in the table below. The table shows the extent of the fall, and the minimum temperature attained within 36 hours.

TABLE XXVIII.—FREQUENCY OF COLD WAVES.

	Nov.		Dec.		Jan.		Feb.		March.		Season.		
	Fall	Min.	Fall	Min.	Fall	Min.	Fall	Min.	Fall	Min.	No.	Gr. fall	Min. temp.
		°	°	°	°	°		°	°	°		°	°
1870-1	..	..	..	..	0	0	21 21	15 20	0	0	2	21	15
1871-2	0	0	27 25 22	12 7 20	0	0	26	15	22 21	9 19	6	27	12
1872-3	0	0	20	8	0	0	27	20	21	7	3	27	20
1873-4	0	0	0	0	0	0	0	0	0	0	0	0	0
1874-5	0	0	28	19	33	1	24	16	25	25	4	33	1
1875-6	25	19	21	15	32	20	20 25	17 16	0	0	5	32	20
1876-7	0	0	21 21	9 13	0	0	0	0	33	22	3	33	22
1877-8	0	0	0	0	0	0	0	0	27	25	1	27	25
1878-9	0	0	0	0	31	1	0	0	0	0	1	31	1
1879-80	0	0	28	18	0	0	0	0	0	0	1	28	18
1880-1	0	0	0	0	27	14	23	16	20	28	3	27	14
1881-2	0	0	0	0	20	20	0	0	0	0	1	20	20
1882-3	0	0	27	12	0	0	0	0	22 26 22	18 25 23	4	27	12
1883-4	0	0	0	0	0	0	28	12	0	0	1	28	12
1884-5	26	28	22	10	25 22	20 11	33 28	5 10	0	0	6	33	5
1885-6	0	0	0	0	0	0	0	0	0	0	0	0	0
1886-7	0	0	22 22	18 15	0	0	0	0	0	0	2	22	15
1887-8	26	26	23	16	0	0	24	11	22	16	4	26	26
1888-9	0	0	0	0	0	0	22	3	0	0	1	22	3
1889-90	0	0	0	0	0	0	0	0	0	0	0	0	0
1890-1	0	0	0	0	0	0	22	16	0	0	1	22	16
1891-2	35 22	22 24	0	0	24 26	13 14	0	0	21	20	5	35	22
1892-3	0	0	0	0	22	5	25 27	12 20	23	18	4	27	20
1893-4	0	0	0	0	25	18	23	13	0	0	2	25	18
1894-5	22	25	0	0	29	12	22	8	0	0	3	29	12
1895-6	21	28	0	0	30	11	34	5	25	19	4	34	5
1896-7	0	0	21	14	20	10	0	0	0	0	2	21	14
1897-8	0	0	0	0	0	0	20	18	0	0	1	20	18
1898-9	0	0	35	13	20 20 24	9 20 18	24	2	0	0	5	35	13
1899-1900	0	0	0	0	25 24	19 8	25	10	28	13	4	28	13
1900-1	0	0	27	16	0	0	0	0	26	13	2	27	16
1901-2	0	0	38	17	22 22	19 20	0	0	22	27	4	38	17
1902-3	0	0	0	0	20	12	0	0	0	0	1	20	12
1903-4	21	24	23	11	22	8	30 20 20	18 8 19	0	0	6	30	18
Total number	8	..	19	..	23	..	25	..	17	..	92	..	..
Average number	0.2	..	0.6	..	0.7	..	0.7	..	0.5	..	2.7	..	..

Table XXVIII shows the frequency of occurrence of a fall of 20° or more in the temperature of two successive days, combined with the attainment of a minimum temperature of 20° or less in December, January and February, or a minimum of 28° or less in March and November.

As a special chapter is to be devoted to an analysis of cold waves in Part II of this Report, reference is here made only to the frequency of their occurrence. In the period comprising 34 winters the total number of occurrences fully satisfying the technical conditions imposed is 92, or an approximate average of three per year. Since 1871 there were three seasons without a cold wave, namely, 1873-74, 1885-86, and 1889-90. The greatest number occurring in any one season was 6, in 1871-72, 1884-85, and in 1903-4. Of the total of 92 in 34 years, 8 occurred in November, 19 in December, 23 in January, 25 in February, and 17 in March. The greatest fall in temperature recorded within the prescribed time of 24 hours was 38°, which occurred in December, 1901. Three cold waves occurred in each of the following months: December, 1871-72, January, 1898-99, February, 1903-04, and March, 1882-83.

Killing Frosts.

A factor of the highest importance, especially to the agricultural and trucking interests of a community, is the average date of occurrence of the first "killing" or "black" frost in autumn, and the last in spring, and their variations in time of occurrence from year to year. Frosts are usually designated as "light," "heavy," or "killing." The term "light" is applied to frosts which are destructive only to tender plants; "heavy" to copious deposits of frost, but which do not destroy the staple products; "killing" to such as are blighting to the staple products of the locality in which the frost occurs. First and last killing frosts are tabulated below for each year from 1871 to 1904 for the vicinity of Baltimore. In the absence of a killing frost before a minimum temperature of 32° was observed, the date of the first record of a freezing temperature was entered in the table. The interval in days between the last frost in spring and the first in autumn is likewise given in order to show the length of the period of safe plant growth.

The average date of occurrence of the last killing frost in spring, based on observations of 34 years, is April 4. It has occurred as early as February 26, namely in 1903, and as late as May 3, as in 1882. The first killing frost in autumn has occurred, on the average on November 3.

The earliest appearance is that of October 6, 1892, and the latest that of December 6, 1878. In the ordinary course of events, accordingly, the period of safe plant growth in the neighborhood of Baltimore, based upon the occurrence of killing frosts, is from April 4 to November 3,

TABLE XXIX.—KILLING FROSTS.

	Last in Spring.		First in Autumn.		Interval in days.
		Min.		Min.	
1871	*Feb. 23	30°	*Nov. 28	31°	....
1872	*Mar. 25	32	* " 16	30	....
1873	" 31	29	Oct. 29	31	212
1874	Apr. 13	29	Nov. 10	31	211
1875	" 22	32	" 3	32	195
1876	" 2	30	Oct. 15	33	196
1877	" 3	32	Nov. 4	37	215
1878	Mar. 26	21	Dec. 6	32	255
1879	Apr. 5	32	Oct. 26	30	204
1880	" 12	30	Nov. 8	35	210
1881	" 21	39	" 27	34	220
1882	May 3	38	" 19	30	200
1883	Apr. 25	34	" 13	32	202
1884	Mar. 30	31	" 7	30	222
1885	" 16	31	" 1	35	230
1886	" 24	29	Oct. 17	36	207
1887	Apr. 6	30	" 31	32	208
1888	Mar. 19	30	" 22	35	217
1889	* " 30	28	Nov. 6	35	...
1890	*Apr. 2	31	Oct. 31	36	....
1891	" 9	36	" 29	33	203
1892	" 15	34	" 6	36	174
1893	" 16	35	" 17	35	184
1894	" 11	32	Nov. 12	27	215
1895	" 11	34	Oct. 29	34	201
1896	" 8	32	Nov. 14	32	220
1897	*Mar. 29	34	Oct. 31	39	....
1898	Apr. 6	26	" 28	34	205
1899	Mar. 25	30	Nov. 4	36	224
1900	" 22	26	" 16	28	239
1901	* " 17	30	" 11	31	....
1902	" 7	31	Oct. 30	34	237
1903	Feb. 26	29	Nov. 7	28	254
1904	Apr. 17	31	.... ..	..	....
Average date 1871-1903	Apr. 4		Nov. 3 ...		213 Average period.
Earliest date	Feb. 26, 1903		Oct. 6, 1892		255 Longest period.
Latest date	May 3, 1882		Dec. 6, 1878		174 Shortest period.

* No frost recorded; first day in Autumn and last day in Spring with a minimum temperature of 32° or below.

or approximately seven months. While this is the most probable length of the period, the interval may be considerably extended by a late autumn frost in conjunction with an early spring frost, or the period may be shortened by a late spring frost followed by an early autumn frost. The extent to which this important interval has

varied in the past 34 years is shown in the above Table XXIX. The shortest interval namely, 5 months and 24 days, was that of 1892, extending from April 15 to October 6; the longest was that of 1878, extending from March 26 to December 6, or 8 months and 15 days. Calculating on the basis of a 34-year record, we find that the last killing frost in spring is likely to occur sometime within the first decade of April once in 4 years; in the second decade once in 5 years; in the third decade once in 11 years; the latest occurrence, as stated above, was May 3, in 1882. In the autumn the first killing frost has occurred but once in 33 years in the first decade of October, three times in the second decade, and ten times in the third decade. It fell within the first decade of November nine times, within the second decade seven times, and within the third decade twice. The latest in 33 years occurred on December 6, 1878.

The First and Last Occurrence of a Minimum of 32°.

Another measure of the period during which staple products are safe from the influence of low temperatures is the last occurrence of a recorded temperature of 32° in spring and the first in autumn. As these records are determined by self-registering instruments they are not subject to the uncertain judgment of observers as to the character and extent of damage inflicted by the frost. Especially is this judgment liable to error in the case of observers stationed within large cities. With a fair exposure of the thermometer, a really injurious frost is not likely to occur with a recorded minimum temperature more than 2° or 3° above the freezing point. The average of the minimum temperatures recorded at the time of occurrence of the "killing frost" in the preceding table, is 31°. It sometimes happens that a temperature several degrees below 32°, sufficient to form heavy ice and seriously injure vegetation, occurs many days and even several weeks after the last recorded "killing frost." Such was the case in 1903, when the last killing frost occurred on the 26th of February, while a temperature of 27° occurred as late as April 5, but without frost. A deposit of frost requires not only a freezing temperature but a high percentage of humidity in the layers of

atmosphere resting upon the ground. Upon the basis of the last and first "freeze" the period of safe vegetable growth is lengthened by about 13 days as compared with the interval between the last and first "killing frost." Table XXX shows an average interval of 226 days between the last occurrence of a minimum temperature of 32° in spring and the first occurrence in autumn. With killing frosts the interval is 213 days. In the exceptionally warm year of 1871 the interval of safe

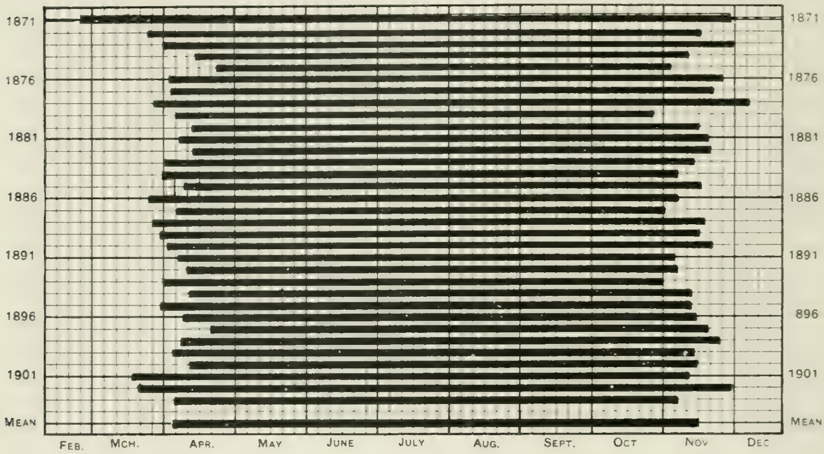


FIG. 33.—Interval Between Last and First Occurrence of a Minimum Temperature of 32° (Heavy Frost).

Fig. 33 shows the time of occurrence of the latest freezing temperature in spring and the first in autumn; also the intervening interval in months and days, for each year from 1871 to 1903. The lowest line, marked "mean" shows the average date of occurrence and the average length of the intervening period. (See Table XXX.)

growth was lengthened to 278 days. In 1875 it was only 195 days. These figures indicate that under the least favorable conditions during the past 33 years the period of entire safety to all excepting tender plants near Baltimore was six months and a half; under the most favorable conditions a trifle over nine months; while the average period is seven months and a half. (See also Fig. 33.) The probability of given departures from the average, or normal, period is shown by the following figures:

FREQUENCY OF STATED DEPARTURES FROM THE AVERAGE LENGTH OF THE PERIOD OF SAFE VEGETABLE GROWTH.

(Number of days.)

Departure.	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	Total
Frequency	10	5	10	3	1	2	1	0	0	0	1	33
In percentage	30	15	30	10	3	6	3	0	0	0	3	100
Cumulative percentage	30	45	75	85	88	94	97	....	....	....	100	....

TABLE XXX.—LAST AND FIRST OCCURRENCE OF A MINIMUM TEMPERATURE OF 32°

Year.	Last in Spring.			First in Fall.			Interval in days.	Departure in days.
	Feb.	Mar.	Apr.	Oct.	Nov.	Dec.		
1871	23	..	..	..	28	..	278	+52
1872	..	25	..	..	16	..	237	+11
1873	..	31	..	..	29	..	243	+17
1874	..	..	13	..	10	..	211	−15
1875	..	..	22	..	3	..	195	−31
1876	..	..	2	..	25	..	237	+11
1877	..	.	3	..	21	..	232	+ 6
1878	..	26	..	..	..	6	255	+29
1879	..	..	5	26	..	..	204	−22
1880	..	..	12	..	15	..	218	− 8
1881	..	..	7	..	24	..	231	+ 5
1882	..	..	12	..	19	..	221	− 5
1883	..	..	1	..	13	..	226	0
1884	..	31	..	..	7	..	221	− 5
1885	..	..	9	..	17	..	222	− 4
1886	..	24	..	..	7	..	228	+ 2
1887	..	..	6	31	..	..	208	−18
1888	..	26	..	..	18	..	237	+11
1889	..	30	..	..	16	..	231	+ 5
1890	..	..	2	.	21	..	233	+ 7
1891	..	..	6	..	4	..	212	−14
1892	..	.	10	..	6	..	210	−16
1893	..	30	..	31	..	..	215	−11
1894	..	..	11	..	12	..	215	−11
1895	..	29	..	..	12	..	228	+ 2
1896	..	..	8	..	14	..	220	− 6
1897	..	..	20	..	18	..	212	−14
1898	..	..	7	..	24	..	231	+ 5
1899	..	..	4	..	13	..	223	− 3
1900	..	..	11	..	14	..	217	− 9
1901	..	17	..	..	11	..	239	+ 1
1902	..	19	..	..	29	..	255	+29
1903	..	..	5	..	6	..	215	−11
1904	..	..	17	..	..	..	...	....
Average date, 1871-1880	..	..	1	..	18	..	231	+ 5
" " 1881-1890	..	..	2	..	14	..	226	0
" " 1891-1900	..	.	7	..	12	..	219	− 7
" " 1871-1902	..	.	3	..	15	..	226	....

The average departure from the normal period of 226 days is about 12 days. In the year 1871 the last freezing temperature occurred 52

days before the average date; the nearest approach to this excessive deviation was a departure of 31 days in the opposite direction in 1875. The figures in the above table indicate that a departure exceeding one month is extremely improbable, having occurred but twice in 34 years. In 28 out of a total of 34 years the limit of variability was under 20 days; in 25 it was under 15 days; in 15 under 10 days; and in 10 under 5 days.

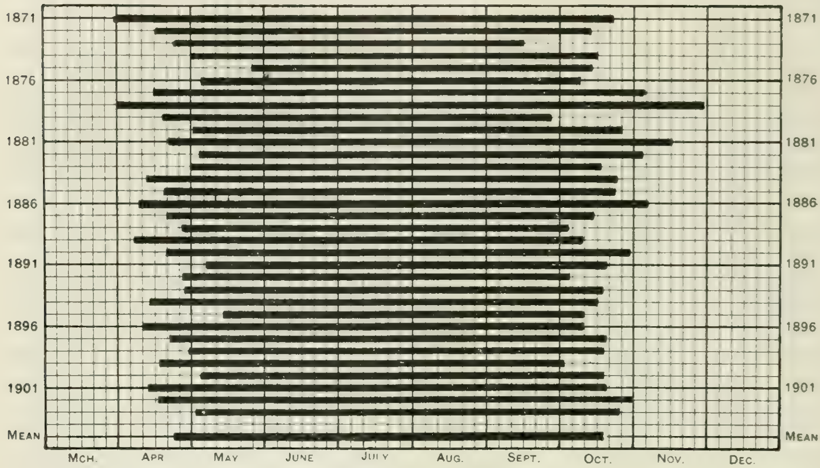


FIG. 34.—Interval Between Last and First Occurrence of Minimum Temperature of 40° (Light Frost).

Fig. 34 shows the time of last occurrence of a minimum temperature of 40° in spring, and that of the first occurrence in fall, together with the length of the intervening period in months and days. The lowest line marked "mean" shows the date of average occurrence and the average length of the intervening period. (See Table XXXI.)

The probability of the occurrence of an injurious freeze some time within the month of April may be expressed by 65 on the basis of a possible 100, a temperature of 32° or less having occurred at some time within the month 22 times in 34 years. The probability of occurrence from the 1st to the 10th of the month is 41; from the 11th to the 20th, 21; from the 21st to the 31st, 3. It has occurred 15 times in 34 years on some day between the 1st and the 10th of April; 7 times from the 11th to the 20th; and 1 time after the 20th. These figures represent the chances of an injurious freeze in the first, second and third decades, respectively, of the month of April.

Light Frosts.

A light frost, injurious only to tender plants, may, and frequently does, occur with a recorded minimum temperature of 40°. Hence the period of safe growth for the frailer varieties of vegetation is reduced

TABLE XXXI.—LAST AND FIRST OCCURRENCE OF A MINIMUM TEMPERATURE OF 40°.

Year.	Last in Spring.			First in Fall.			Interval in days.	Departure in days.
	Mar.	Apr.	May	Sept.	Oct.	Nov.		
1871	29	..	..	..	21	..	206	+27
1872	..	16	..	..	12	..	179	0
1873	..	23	..	15	..	..	145	−34
1874	..	30	..	..	15	..	168	−11
1875	..	..	26	..	13	..	140	−39
1876	..	..	4	..	8	..	157	−22
1877	..	15	..	..	..	4	203	+24
1878	30	..	..	..	..	29	244	+65
1879	..	18	..	26	..	..	161	−18
1880	..	..	1	..	25	..	177	− 2
1881	..	21	..	..	..	15	208	+29
1882	..	..	3	..	..	3	184	+ 5
1883	..	30	..	.	16	..	169	−10
1884	..	12	..	..	23	..	194	+15
1885	..	19	..	..	22	..	186	+ 7
1886	..	9	..	..	..	5	210	+31
1887	..	20	..	..	13	..	176	− 3
1888	..	26	..	..	3	..	160	−19
1889	..	7	..	..	9	..	185	+ 6
1890	..	20	..	..	28	..	191	+12
1891	..	..	6	..	18	..	165	−14
1892	..	26	..	..	3	..	160	−19
1893	..	27	..	..	17	..	173	− 6
1894	..	13	..	..	15	..	185	+ 6
1895	..	..	13	..	9	..	149	−30
1896	..	10	..	..	9	..	182	+ 3
1897	..	21	..	..	18	..	180	+ 1
1898	..	29	..	..	17	..	171	− 8
1899	..	17	..	..	1	..	167	−12
1900	..	..	4	..	17	..	166	−13
1901	..	12	..	..	18	..	189	+10
1902	..	16	..	..	29	..	196	+17
1903	..	..	2	..	19	..	170	− 9
1904	..	22	..	..	..	..	...	....
Average date, 1871-1880	..	22	..	..	17	..	178	− 1
" " 1881-1890	..	20	..	..	23	..	186	+ 7
" " 1891-1900	..	26	..	..	12	..	169	−10
" " 1871-1902	..	22	..	..	18	..	179	....

still more. A minimum of 40° has been recorded at Baltimore as late as May 26, namely in 1875; but this is an exceptional case. The last spring minimum of 40° has occurred as early as March 29. The dates of the last in spring and first in autumn, with the length of the

intervening interval in days, is shown in Table XXXI. This interval is also shown graphically in Fig. 34.

The Period of Effective Temperatures for Plant Growth.

It is generally conceded that every plant requires a certain temperature in order to develop successively the leaf, bud and fruit; that there is a minimum temperature below which physiological activity in the plant ceases, and hence that only temperatures above this limit are effective in carrying the plant forward from the sprouting of the seed to the maturity of the fruit. This "critical" point in the history of plant growth is assumed to be a mean daily temperature of 43° F. In order

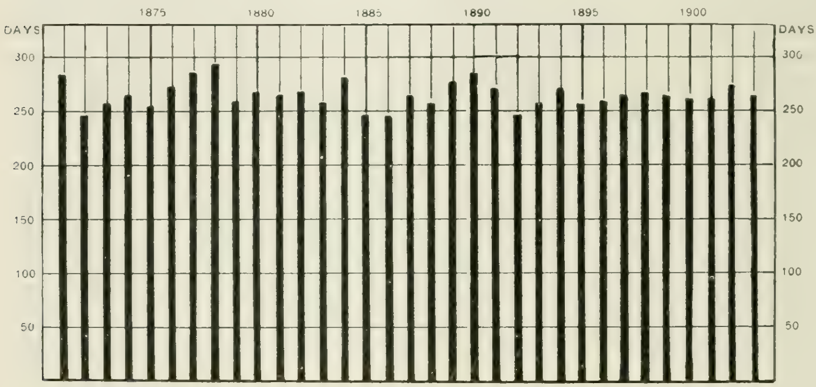


Fig. 35.—Annual Number of Days with Mean Temperature above 42°.

Fig. 35 shows the total annual number of days having a mean temperature of 43° or above, the degree of heat which marks the beginning of physiological activity in plants.

to determine the number of days in the year during which this "effective" temperature prevails in the vicinity of Baltimore, the days with a mean daily temperature of 43° or above from 1871 to 1903 have been tabulated. The normal number of such days for each month and for the year is shown in the following table, while the variation in the total annual number is represented in Fig. 35.

PERIOD OF EFFECTIVE TEMPERATURES FOR PLANT GROWTH.

(Average number of days.)

Means.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1871-1902..........	5.3	6.5	14.1	27.0	31.0	30.0	31.0	31.0	30.0	30.6	19.4	8.2	264

The first appearance of a daily mean temperature of 43° in spring normally falls upon the 25th day of March, and the last upon the 27th day of November, an interval of 245 days, or about eight months. However, such days occur throughout the year and are probably effective in directly or indirectly promoting physiological activity in the plant. Hence to the period above mentioned must be added the days of the winter and early spring months before the permanent appearance of the daily mean of 43°. This will materially increase the annual period of "effective" temperatures, as a considerable proportion of the winter days fall within the prescribed limit. Calculating on this basis the average period comprises 264 days. The longest period, namely, that

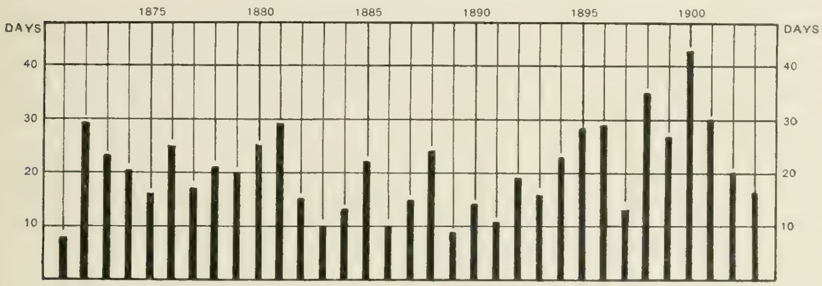


FIG. 36.—Annual Number of Days with Maximum Temperature of 90° and over. (See Tables XXXII and XXXIII.)

of the year 1878, contained 293 days, and the shortest, 244 days in 1886. The ten year average values of the three decades from 1871-1900 varied only from 261 days to 268 days, showing a remarkably constant average length for this period.

THE FREQUENCY OF WARM DAYS IN SUMMER.

It is a well recognized fact of observation that the temperatures above the normal heat of a locality fluctuate to a less degree than the temperatures below the normal. In other words the extent of variability in the temperature for a given locality is generally determined by the cold days and not by the warm. The extreme maximum temperature in the United States has a range of about 40°, or from 80° to 120°; the

extreme minimum varies from 65° below zero to about 40° above, a range of 105°. While variability in the temperature of warm days is of less importance in agricultural and mercantile life than that of cold days, it is a factor of much concern in personal comfort, especially to the dwellers in large cities.

TABLE XXXII.—LIST OF WARM DAYS.—APRIL.

(Temperature of 90° or above.)

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	
1888																													90		1
1896																		94	93												2
1903																														91	1
																															4

MAY.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	
1877																		92	92													2
1879																															94	1
1880									91								90	90		91					90	92	93					7
1881											91	94	95																			3
1889									90	93																						2
1895																														95	95	2
1896									93	96	94						93	92														5
1898																				92												1
1899																												90				1
1900													91	91	94																	3
1902																							90									1
1903																				92												1
																																29

Table XXXII contains a complete list of all days from 1871 to 1903, during which the temperature rose to 90° or above; together with the maximum temperature recorded on such days and the monthly frequency of occurrence. Fig. 36 shows the annual frequency of days upon which the maximum temperature equalled or exceeded 90°.

The frequency of occurrence of days with an excessively high temperature hence plays an important part in the composition of local climates. We can provide against extreme cold in winter; from the hot and enervating summer weather there is no escape for the great numbers who are compelled by circumstances to remain in the large cities beyond the reach of mountains or seashore.

A temperature below 90° is not especially uncomfortable or unwholesome unless accompanied by a high degree of humidity and a stagnant

atmosphere. Defining a hot day as one with a temperature of 90° or above, the Baltimore statistics show a frequency and distribution indicated in Table XXXII.

TABLE XXXII.—LIST OF WARM DAYS.—JUNE.

(Temperature of 90° or above.)

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	
1871																												91			1
2									90			90									91							92		94	5
3																			93			90									2
4							90	96	98									90					95	93		91		93	97		9
5																							96	96	95	97	94	93	90		7
6																								90	90	94	95	93			5
7			90																93						92	95					4
8																											92				1
9	94									90					90												92	92			5
1880												95	92									92	93	95	93	90	91	94			9
1																			91									92	92		3
2															90			90						91	97	92	90				6
3						90																									1
4																			91	91	92	93									4
5					91									95	90	94															4
6																															0
7																	93	94													2
8															92	94	90				92	94	92	93	92						8
9																				90	91										2
1890				91	90																				93	93					4
1			90												93	94	90									91					5
2													93	94			91	90	91				93								6
3											92								93	98	90	92									5
4				90							90	90					91				90	91	97	98							8
5	97	95	97																	91			91								5
6																				92	93	90									3
7																									92					95	2
8									90			91												90	98	95		94		90	7
9					93	98	96	95						90	93					92				94							8
1900								91			92																93	91	93		5
1												92										90				92	92	93	96	99	7
2			93									91	94																91		4
3																															0
																															147

Such days do not generally make their appearance until the month of June and disappear in the first week of September. The average number for the entire season is 21, and the monthly distribution is as follows: June 4, July 10, August 5, and September 2. They occasionally occur in May (about one in two years on the average), and have occurred on two occasions in 33 years as early as April and once as late as October. There is considerable difference in their total frequency during

a period of 10 years: From 1871 to 1880 there were 204; from 1881 to 1890, 161; from 1891 to 1900, 243. The annual frequency has varied from 8 in 1871 to 43 in the memorable summer of 1900, as shown in Fig. 36. It is remarkable that the summer containing the highest total

TABLE XXXII.—LIST OF WARM DAYS.—JULY.

(Temperature of 90° or above.)

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	
1871	..	..	..	..	..	..	90	..	91	91	..	..	..	..	90	92	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5
2	96	97	96	93	93	..	..	..	..	93	..	..	91	92	..	91	91	95	..	..	..	..	..	..	..	94	..	..	..	..	..	12
3	..	93	96	92	91	..	..	..	..	..	..	..	..	94	91	90	93	96	..	..	..	..	90	92	94	92	..	..	..	91	90	15
4	..	..	..	92	..	..	..	92	92	96	..	..	..	92	94	..	..	..	..	91	..	..	..	..	..	..	..	..	..	..	..	7
5	..	..	..	..	92	94	..	..	..	..	90	..	90	..	..	91	..	96	..	..	..	..	..	..	..	94	..	..	..	..	..	7
6	..	94	93	95	92	90	..	97	99	97	96	96	95	91	91	90	90	93	92	97	..	..	..	..	..	..	..	..	..	..	..	18
7	92	..	..	..	..	..	..	..	91	..	..	..	..	..	..	91	..	..	..	..	..	..	..	..	92	92	93	92	..	92	..	8
8	..	..	..	92	92	92	90	92	91	94	91	..	..	91	92	..	91	98	96	92	95	..	..	..	..	91	..	..	..	..	..	16
9	..	..	95	98	..	..	..	..	..	92	95	..	..	..	94	99	91	..	..	..	..	90	92	..	..	..	90	..	..	..	..	10
1880	..	..	..	..	..	..	..	..	93	97	94	90	99	90	91	94	90	..	..	..	..	..	..	..	..	90	..	..	..	..	..	10
1	..	..	91	93	96	96	91	..	..	..	90	..	95	92	..	91	..	..	..	..	..	..	..	90	90	..	..	..	..	..	..	11
2	..	..	..	..	..	..	..	..	90	93	90	..	..	..	..	..	..	..	..	..	..	..	..	91	90	93	91	93	..	..	..	8
3	..	91	92	94	..	94	93	..	..	..	..	..	..	..	..	..	..	..	..	..	..	96	95	..	..	..	..	..	..	..	..	7
4	..	..	..	..	..	..	..	..	..	..	..	..	91	..	..	..	..	..	..	..	..	..	93	95	..	..	..	..	..	..	..	3
5	..	..	..	..	..	..	91	92	94	92	..	..	..	..	..	92	95	96	93	98	99	93	92	92	96	94	..	..	..	..	..	15
6	..	..	..	..	..	..	92	90	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	90	91	..	4
7	90	..	..	..	..	..	..	..	..	..	90	92	96	95	..	101	99	102	..	..	..	..	..	..	..	..	..	..	93	92	..	10
8	..	..	..	..	91	..	94	..	..	..	..	90	..	..	..	..	..	..	..	..	..	..	90	90	..	..	..	..	..	..	..	5
9	..	..	..	..	..	..	..	92	93	..	90	..	..	90	..	..	..	..	..	90	..	..	..	..	..	..	..	..	..	..	..	5
1890	..	..	..	91	..	..	..	98	90	..	..	..	..	..	91	92	97	..	..	..	..	..	..	..	..	..	..	..	..	92	95	8
1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0
2	..	..	..	..	..	..	..	..	..	..	..	..	91	..	90	..	..	..	..	..	..	..	..	94	97	99	97	95	97	91	90	10
3	..	..	..	..	91	..	..	..	..	..	..	..	94	..	..	92	90	92	..	..	..	91	..	..	92	96	..	..	90	..	..	9
4	91	..	..	..	..	..	..	..	..	..	..	95	97	90	..	..	..	..	94	97	..	..	..	..	91	93	92	97	95	..	..	11
5	..	..	..	..	..	..	..	..	90	..	..	..	..	..	..	..	90	92	..	93	95	..	..	..	..	..	..	..	..	..	..	5
6	..	..	90	..	..	..	..	..	..	..	90	92	93	91	..	..	..	..	..	90	..	..	..	..	..	..	96	92	94	92	..	10
7	..	91	..	..	..	90	..	..	..	90	..	..	..	..	..	..	..	..	..	..	..	..	94	..	..	..	..	..	..	..	..	4
8	100	97	104	100	..	..	..	91	..	..	..	..	..	..	91	..	..	..	..	..	92	..	..	..	..	..	..	..	94	94	90	10
9	..	..	90	90	..	..	..	..	..	..	..	91	93	..	..	92	..	..	..	..	94	96	..	..	..	..	92	..	..	..	..	8
1900	..	..	92	97	94	96	96	93	..	..	94	93	..	..	96	100	100	98	..	91	96	..	..	..	91	..	..	..	..	..	..	15
1	103	103	97	96	94	96	90	..	..	..	..	..	..	..	..	90	..	90	93	90	92	93	94	93	94	..	..	90	96	95	..	19
2	..	..	97	..	95	95	..	92	93	..	..	..	..	91	92	..	96	99	..	95	..	..	..	..	..	..	..	..	..	..	..	10
3	93	95	95	..	..	..	..	90	95	96	95	..	..	..	..	..	..	..	..	..	..	..	..	90	91	94	..	..	92	95	..	12
																																307

number of excessively hot days in a period of 33 years did not have an *average* temperature sufficiently high to class the *season* as excessively warm. The "hot-spell" occurred late in July and in August and was followed by an exceptionally warm autumn. This period will receive further attention in Part II, in the discussion of summer weather.

Inspection of Fig. 36 reveals a strikingly uniform increase in the num-

ber of days with a maximum temperature of 90° and above since the year 1889. Starting with a frequency of 9 in the latter year, the number rose steadily to 43 in 1900 with but one marked interruption and two or three minor ones. Since 1900 there has been a steady fall, repre-

TABLE XXXII.—LIST OF WARM DAYS.—AUGUST.

(Temperature of 90° or above.)

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	
1871															90	91																2
2										92	92	94	95	96	90			90	93	93	91	96				92						12
3	94	91	90																				90									4
4																		91		97	96											3
5																																0
6							90										90															2
7								92																				90	94			3
8	91	90							92	91																						4
9		92	92	90	90	90																										5
1880																									90				91			2
1			92	94	94	93				93			98																	90	91	8
2							90																									1
3																			92	92												2
4																			92	94	91											3
5													90											94	92							3
6											90						90										92	90				4
7						90					91	91																				3
8			90	94	93	90	93	94	90						90	96	90															10
9																					90											1
1890	95																91															2
1									92	94	94	91											90									5
2									95	95	92																					3
3												90															90					2
4								93	90																							2
5								91	94	96	95	91				90								94		90		91	92			10
6				91	96	94	98	94	97	90	95	97	92																			10
7														90																		1
8				93			93	92									92						93	94	90					91	95	9
9		90	90	91	93								91							97	97	90										8
1900						97	100	99	100	100	100	99	92	94	90	91	92	91	92							96	92				93	17
1										93											90	90										3
2		90	91	90							90																					4
3																								93	97							2
																																150

sented by the figures 43, 30, 20, 16. The numbers for the rising branch of the curve of frequency are: 9, 14, 11, 19, 16, 23, 28, 29, 12, 35, 27, 43.

The real discomfort of a hot summer depends not so much on the actual number of hot days as the length of the periods of uninterrupted hot weather. A month, for example, with 10 scattered days having a temperature exceeding 90° would be far more comfortable than one with an equal number of consecutive days with the same degree of heat. In

fact, hot spells of the latter description are of comparatively rare occurrence in Baltimore, not having occurred more than five times in 33 years,

TABLE XXXII.– LIST OF WARM DAYS.—SEPTEMBER.

(Temperature of 90° or above.)

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	
1871																															0
2								94	92																						2
3	93				90																										2
4								90				90																			2
5			92	90																											2
6																															0
7																															0
8																															0
9																															0
1880				91	91	90																									3
1						93	101	93																	90	90	90				6
2																															0
3																															0
4						90	90		92	98																					4
5																															0
6																	90											91			2
7																															0
8																															0
9																															0
1890																															0
1																		90													1
2																															0
3																															0
4									94	94																					2
5											90	93								90	96	96	95			93					7
6			91							91									94												3
7									91	92	97		93																		4
8	95	96	97	91	90	93	93											91													8
9						94		90																							2
1900			90			94	91				95																				4
1															92																1
2	92																														1
3																															0
																															56

OCTOBER.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	
1897																90																1
																																1

while the former condition has occurred about 25 times. A list of the longest periods of consecutive days with a maximum temperature of 90° or above for each year from 1871 to 1903 is published in Table XXXIII. The table likewise shows the dates of beginning and ending of the periods

and the maximum temperatures attained. Their annual average length is a little less than six days, with limits of variations between 2, as in 1871, 1886 and 1889, and 14 in 1900. The season with the longest hot spell on record likewise contained some of the highest temperatures ever

TABLE XXXIII.—LONGEST PERIOD OF CONSECUTIVE DAYS WITH A MAXIMUM TEMPERATURE OF 90° OR ABOVE.

	Began.	Ended.	Length.	Max. temp.
			Days.	
1871	July 9	10	* 2	91°
1872	June 30	July 5	* 6	97
1873	July 14	18	* 5	96
1874	June 7	9	* 3	98
1875	June 23	29	7	97
1876	July 8	20	13	99
1877	July 25	28	4	93
1878	July 4	11	8	94
1879	Aug. 2	6	5	92
1880	July 9	17	9	99
1881	July 3	7	5	96
1882	July 24	28	5	93
1883	July 2	4	3	94
1884	June 19	22	4	93
1885	July 16	26	11	99
1886	July 7	8	* 2	92
1887	July 11	14	4	96
1888	Aug. 3	9	7	94
1889	July 8	9	* 2	93
1890	July 30	Aug. 1	* 3	95
1891	Aug. 9	12	4	94
1892	July 24	31	8	99
1893	June 19	22	4	98
1894	July 25	29	5	97
1895	May 30	June 3	* 5	97
1896	Aug. 4	13	10	98
1897	Sept. 9	11	3	97
1898	Aug. 30	Sept. 7	9	97
1899	June 5	8	* 4	98
1900	Aug. 6	19	14	100
1901	June 26	July 7	12	103
1902	Aug. 2	4	3	91
1903	July 8	11	4	96
Average			5.8	

* Two periods of equal length; the period with the highest maximum temperature selected.

recorded in Baltimore. On six successive days the maximum temperature ranged between 99° and 100°; the month contained 17 hot days, and was preceded by a month with 15. This was doubtless the most trying period in the history of Baltimore summers. A more extended account of this remarkable hot spell will be given in Part II of this Report.

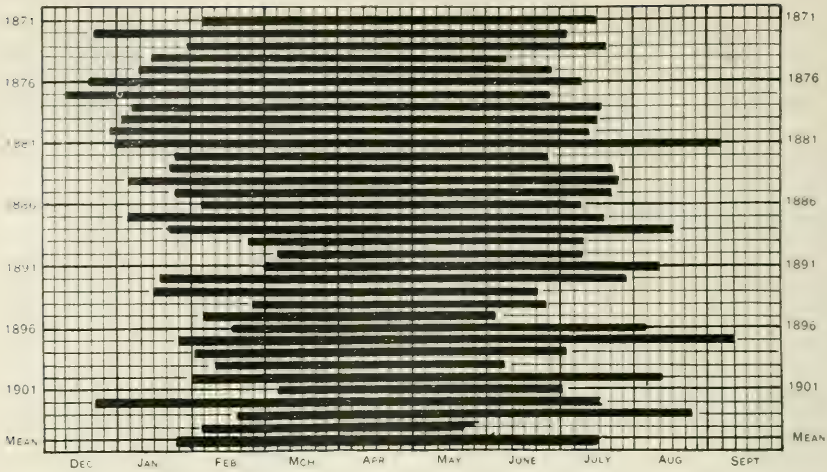


FIG. 37.—Time of Occurrence of the Lowest and Highest Temperature of the Year.

Fig. 37 shows the time of occurrence of the lowest temperature of each winter season, from 1871 to 1904, and of the highest temperature of each succeeding summer season, from 1871 to 1903; also the length of the intervening period in months and days. The lowest line marked "mean" shows the average time of occurrence and the average length of the intervening period. The line for 1904 shows only the time of occurrence of the lowest temperature. (See Table XXXIV.)

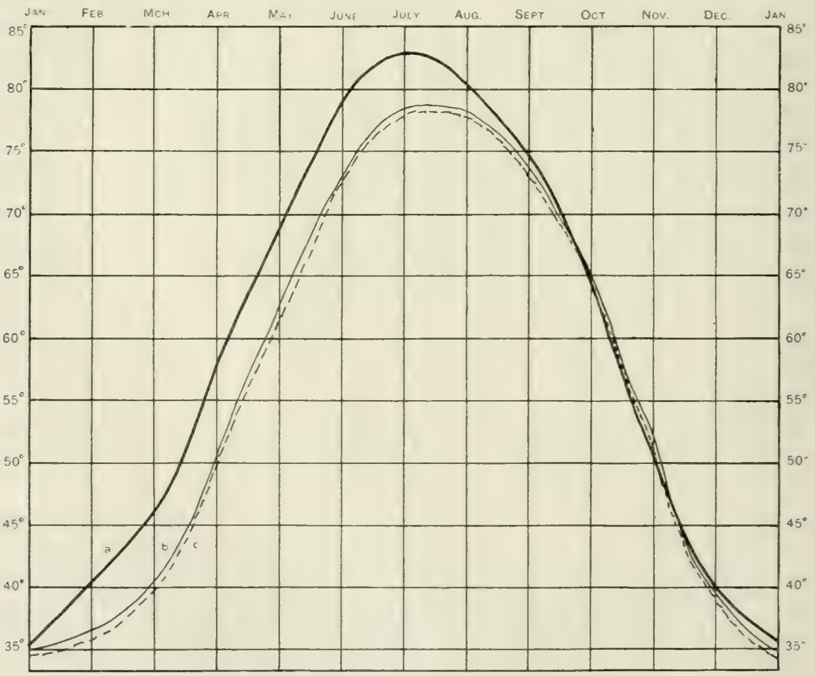


FIG. 38.—(*a*) Air Temperature at 2 p. m. (Harbor).
(*b*) Temperature of Surface Water, 2 p. m. (Harbor).
(*c*) " " Water at depth of 10 ft. (Harbor).

Fig. 38 shows the mean monthly temperature of the water in the harbor, and of the air at 2 p. m., at the foot of South street. (*a*) Air temperature; (*b*) temperature of the water at the surface; (*c*) temperature of the water at the bottom (10 ft). See Table XXXV.

TIME OF OCCURRENCE OF ANNUAL MINIMUM AND MAXIMUM TEMPERATURES.

The dates of occurrence of the winter minimum and the summer maximum temperatures, and the length of the intervening period, are ex-

TABLE XXXIV.—TIME OF OCCURRENCE OF ANNUAL MINIMUM AND MAXIMUM TEMPERATURES.

Winter.	Min.	Date of minimum.				Date of maximum.				Max.	Summer.
		Dec.	Jan.	Feb.	Mar.	June	July	Aug.	Sept.		
1870-1	10°	..	..	6	..	..	16	..	..	92°	1871
1871-2	5	21	..	..	..	..	2	..	..	97	1872
1872-3	—4	..	30	..	..	..	18*	..	..	96	1873
1873-4	13	..	16*	..	..	9	..	..	..	98	1874
1874-5	—2	..	10	..	..	27	..	..	..	97	1875
1875-6	12	18	..	..	..	..	9	..	..	99	1876
1876-7	1	10	..	..	..	26	..	..	..	95	1877
1877-8	6	..	8	..	..	..	18	..	..	98	1878
1878-9	0	..	3	..	..	..	16	..	..	99	1879
1879-80	13	27	..	..	..	..	13	..	..	99	1880
1880-1	—6	..	1	..	..	..	..	..	7	101	1881
1881-2	7	..	24	..	..	25	..	..	..	97	1882
1882-3	11	..	23	..	..	..	22	..	..	96	1883
1883-4	8	..	6	..	..	..	24	..	..	95	1884
1884-5	3	..	..	11	..	..	21	..	..	99	1885
1885-6	—1	..	..	5	..	..	7	..	..	92	1886
1886-7	7	..	3	..	..	..	18	..	..	102	1887
1887-8	9	..	22	..	..	..	..	16	..	96	1888
1888-9	3	..	..	24	..	..	9	..	..	93	1889
1889-90	12	..	..	..	7	..	8	..	..	98	1890
1890-1	16	..	..	..	2	..	..	11	..	94	1891
1891-2	12	..	17	..	..	..	26	..	..	99	1892
1892-3	1	..	16	..	.	20	..	..	..	98	1893
1893-4	8	..	..	25	..	24	..	..	..	98	1894
1894-5	1	..	..	6	..	3	..	..	..	97	1895
1895-6	5	..	..	17	..	..	..	7	..	98	1896
1896-7	8	..	26	..	..	..	..	..	11	97	1897
1897-8	10	..	..	2	..	..	3	..	..	104	1898
1898-9	—7	..	..	10	..	6	..	..	..	98	1899
1899-1900	8	..	..	1	..	..	17	..	..	100	1900
1900-1	13	..	..	..	6	..	2	..	..	103	1901
1901-2	11	22	..	..	..	..	18	..	..	99	1902
1902 3	5	..	..	19	..	..	..	25	..	97	1903
1903-4	2	..	5	..	..	..	..	..	..	..	1904
No. of occurrences	..	5	15	11	3	8	19	4	2	..	....
Mean	..	8.°4	4.°8	4.°1	13.°7	97.°2	97.°9	96.°2	99.°0	..	....

* On other days also.

ceedingly variable quantities. While the lowest winter temperature usually occurs in January, it has on several occasions appeared in December, frequently in February, and occasionally in March, in the past 34 years. The earliest occurrence was on the 10th of December in 1876, the latest on the 7th of March in 1890.

TABLE XXXV.—MEAN TEMPERATURE OF AIR AND OF SURFACE WATER IN THE HARBOR AT 2 P. M.

Date.		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	Air	39.6	36.2	42.1	54.1	62.8	78.1	78.3	81.4	77.1	70.7	61.2	43.0
	Water	*37.6*	*34.3*	*37.1*	*45.0*	*57.6*	*67.4*	*75.8*	*79.7*	*76.8*	*69.8*	*59.2*	*46.2*
2		35.5	35.3	46.3	58.4	68.3	74.4	78.1	80.3	75.2	66.5	60.3	40.7
		36.7	*34.0*	*37.7*	*45.7*	*58.3*	*67.7*	*75.9*	*79.8*	*76.7*	*69.0*	*58.7*	*45.5*
3		36.7	40.5	42.6	52.9	65.8	76.0	82.8	79.0	78.2	66.4	53.4	38.4
		36.9	*34.6*	*37.5*	*46.0*	*59.0*	*67.9*	*76.3*	*78.9*	*76.6*	*68.7*	*57.7*	*44.8*
4		36.5	35.2	43.7	51.0	69.7	76.8	80.9	80.6	79.0	68.1	55.5	40.2
		36.4	*34.6*	*36.8*	*46.0*	*59.3*	*68.3*	*76.8*	*78.6*	*76.6*	*68.6*	*57.4*	*44.1*
5		28.8	37.0	42.4	55.1	69.0	79.9	81.3	80.5	78.8	68.6	59.1	42.9
		36.3	*34.6*	*37.2*	*46.6*	*59.2*	*69.2*	*77.0*	*79.1*	*76.8*	*68.5*	*57.1*	*43.6*
6		32.1	39.2	43.2	55.3	65.9	77.9	83.6	78.6	77.2	67.1	57.0	44.2
		35.9	*34.1*	*37.9*	*47.0*	*59.2*	*70.1*	*77.5*	*78.7*	*76.7*	*67.8*	*56.7*	*43.4*
7		38.3	45.0	41.7	56.8	61.6	79.9	85.3	76.4	77.7	67.7	52.0	38.4
		35.8	*34.0*	*38.0*	*47.6*	*59.4*	*70.6*	*77.8*	*78.0*	*76.4*	*67.6*	*56.3*	*42.7*
8		39.0	43.7	35.7	55.5	63.9	79.2	84.7	79.2	78.5	66.8	53.9	41.3
		35.7	*34.0*	*38.2*	*47.9*	*59.6*	*71.2*	*77.8*	*78.2*	*76.3*	*67.1*	*55.3*	*42.4*
9		38.1	42.1	39.3	51.8	73.3	77.7	81.5	78.8	77.7	67.9	54.3	43.7
		35.8	*34.4*	*38.1*	*47.6*	*59.6*	*71.0*	*77.5*	*78.2*	*76.4*	*67.3*	*54.9*	*41.9*
10		31.5	41.0	46.6	52.5	69.0	81.8	85.6	79.0	77.3	69.1	56.6	45.5
		35.2	*34.5*	*38.3*	*48.1*	*60.8*	*71.8*	*77.6*	*78.1*	*76.1*	*67.5*	*54.7*	*41.7*
11		35.8	35.7	43.7	48.2	64.6	77.5	83.2	81.6	73.2	71.5	59.7	44.5
		35.4	*34.5*	*38.7*	*48.7*	*60.6*	*72.9*	*77.7*	*78.3*	*75.7*	*67.2*	*54.5*	*41.3*
12		34.8	43.7	48.1	54.9	63.0	79.2	82.6	81.2	73.3	70.9	55.1	41.6
		35.0	*34.8*	*38.8*	*48.8*	*61.0*	*73.6*	*77.9*	*78.1*	*75.2*	*66.8*	*54.3*	*40.4*
13		34.4	46.7	45.4	58.1	59.0	79.9	80.2	84.7	73.3	72.5	53.9	43.0
		35.2	*35.4*	*39.5*	*49.8*	*60.5*	*73.7*	*77.7*	*78.3*	*74.1*	*66.8*	*53.6*	*40.4*
14		36.9	45.6	47.0	57.3	60.9	77.0	79.4	82.5	76.7	69.4	47.6	43.6
		34.8	*36.1*	*39.9*	*50.4*	*60.5*	*72.6*	*77.9*	*78.7*	*74.1*	*66.3*	*53.0*	*40.2*
15		35.6	45.6	50.9	54.3	68.1	79.3	81.1	78.8	76.4	62.7	48.4	37.2
		34.5	*36.6*	*40.5*	*50.6*	*60.8*	*73.9*	*78.0*	*78.2*	*74.1*	*66.0*	*52.5*	*39.9*
16		38.2	42.2	46.8	57.5	67.1	80.5	83.2	78.4	78.0	60.7	47.8	34.7
		34.4	*36.3*	*40.1*	*51.4*	*61.0*	*74.5*	*78.2*	*78.0*	*74.0*	*65.2*	*51.8*	*39.7*
17		35.1	41.9	45.2	59.3	66.2	79.3	82.1	82.5	79.1	64.2	52.6	36.3
		34.3	*36.1*	*40.2*	*51.4*	*61.0*	*75.3*	*78.2*	*78.2*	*74.5*	*64.6*	*51.5*	*38.7*
18		35.1	41.9	46.9	63.9	69.0	80.6	84.0	81.6	73.8	67.8	48.7	38.0
		34.2	*36.5*	*40.6*	*52.0*	*61.6*	*75.1*	*79.4*	*78.1*	*74.4*	*65.4*	*51.3*	*38.1*
19		36.2	41.0	49.9	65.2	69.1	80.0	84.6	83.8	76.4	66.6	47.9	34.8
		34.1	*36.2*	*40.9*	*53.2*	*62.3*	*75.7*	*79.1*	*78.4*	*74.0*	*65.0*	*50.8*	*38.2*
20		34.5	35.5	41.9	64.6	71.5	80.7	83.0	83.4	76.8	68.0	48.9	32.2
		34.2	*35.7*	*40.9*	*54.1*	*62.8*	*76.4*	*79.1*	*78.3*	*73.0*	*64.6*	*50.2*	*38.0*
21		36.6	38.3	45.2	63.6	73.3	81.5	82.5	84.5	72.7	61.5	49.7	42.0
		33.7	*36.0*	*40.5*	*54.5*	*64.1*	*76.2*	*79.0*	*78.4*	*72.6*	*64.2*	*49.7*	*37.3*
22		32.3	38.0	41.2	63.8	73.1	80.3	87.6	81.3	68.8	61.4	51.6	43.9
		34.0	*36.9*	*40.6*	*55.3*	*64.4*	*76.1*	*79.4*	*78.8*	*72.0*	*63.0*	*49.3*	*37.8*
23		29.4	38.3	39.3	61.5	73.3	79.8	87.9	80.8	70.6	57.8	56.5	38.2
		33.5	*36.6*	*41.2*	*55.5*	*66.1*	*75.7*	*79.5*	*78.4*	*71.6*	*62.9*	*49.5*	*37.3*
24		27.5	36.8	47.3	65.0	71.9	83.1	86.7	83.0	72.0	57.8	46.8	40.8
		33.3	*36.6*	*41.7*	*55.9*	*65.6*	*76.0*	*79.5*	*78.2*	*71.1*	*62.5*	*49.2*	*37.6*
25		32.2	44.3	49.2	59.9	70.0	82.0	84.0	83.0	72.4	60.9	43.1	36.7
		32.9	*36.7*	*42.3*	*56.5*	*65.0*	*76.1*	*79.2*	*78.2*	*70.9*	*62.6*	*48.4*	*37.3*
26		36.5	40.0	53.6	62.1	71.6	77.9	85.0	80.1	69.6	59.4	42.8	33.7
		33.1	*36.6*	*42.6*	*56.4*	*65.2*	*76.3*	*79.8*	*78.0*	*70.6*	*61.9*	*47.4*	*36.5*
27		36.0	42.2	53.5	65.8	72.9	77.5	83.5	77.5	73.0	59.5	44.7	36.4
		33.0	*36.3*	*43.0*	*57.0*	*65.5*	*76.3*	*79.5*	*77.6*	*70.8*	*61.2*	*47.0*	*35.8*
28		35.8	43.3	52.8	67.5	73.8	79.2	82.1	77.5	77.8	59.7	45.6	39.3
		33.7	*37.3*	*43.9*	*57.8*	*65.7*	*76.7*	*79.7*	*77.5*	*71.0*	*67.0*	*46.8*	*36.3*
29		36.8	....	46.7	61.4	69.7	80.7	82.9	76.0	72.5	60.1	42.4	40.2
		34.1	....	*43.1*	*57.4*	*66.2*	*76.9*	*79.9*	*77.5*	*70.5*	*60.6*	*46.5*	*36.2*
30		37.4	....	48.6	63.5	70.4	76.7	83.3	76.9	73.7	58.9	43.0	39.8
		34.0	....	*42.8*	*57.6*	*66.8*	*76.2*	*79.8*	*77.5*	*70.0*	*60.2*	*46.3*	*35.7*
31		42.3	...	53.3	....	73.2	....	82.5	76.9	....	58.6	....	46.9
		34.4	....	*43.1*	....	*67.0*	....	*79.7*	*77.1*	....	*59.7*	....	*36.2*
Monthly Average	Air	35.4	40.7	45.8	58.7	68.4	79.1	83.0	80.3	75.2	64.8	51.3	40.1
" "	Water	*34.8*	*35.5*	*40.1*	*51.4*	*62.1*	*73.4*	*78.3*	*78.3*	*74.0*	*65.2*	*52.4*	*39.8*

Annual average: Air 60.2; Water *57.1*.

Table XXXV shows the average daily temperature of the surface water in the harbor, and of the air, at 2 p. m., for the period of five years from 1882 to 1886. The roman figures show the air temperature, and the italic figures the water temperature.

The highest annual temperature occurred in July in the great majority of cases in the past 34 years; it has never appeared earlier than June 3; on two occasions it fell in the months of September, on the 7th in 1881, and on the 11th in 1887. The average interval between the occurrence of the lowest and highest temperatures of the year is 181 days, from January 25 to July 15. The longest was 250 days, from January 1 to September 7, 1880; the shortest was 116 days, from February 10 to June 6, 1899.

The details of occurrence, together with the minimum and maximum temperatures recorded, are shown for each year since 1871 in Table XXXIV. The length of the intervening period is represented graphically in Fig. 37.

Temperature of the Water in the Harbor.

From September 1, 1881 to March 31, 1887, observations were made daily at 2 p. m. of the temperature of the surface water in the harbor, from the wharf at the foot of South Street. At the same time the temperature at the bottom (a depth varying from 9 to 12 feet according to the tide) and the temperature of the air were also noted. The average values of the surface water temperature and the air temperature for the five years from 1882 to 1886 are presented in Table XXXV. Fig. 38 also shows graphically the mean temperature of the water at the surface, and at the bottom, and of the air at 2 p. m. The temperature of the surface water is approximately 5° to 6° cooler than the air temperature from February to July. The difference diminishes gradually from July to October. In October the temperatures are approximately equal, and remain so until December when there is again a gradual divergence. The difference between the temperature of the surface water and that at a depth of ten feet is very small at all seasons of the year, averaging about five-tenths of a degree.

HUMIDITY.

Introduction.—Two distinct gaseous envelopes surround the earth; one is the dry air, with small quantities of other relatively permanent gases; the other is the vapor of water which may be condensed into visible forms of dew, frost, cloud, rain or snow, under ordinary conditions of temperature and pressure.

It is of the highest importance, in the consideration of climatic conditions, to understand the functions and the distribution of the element of water in the atmosphere, in its great variety of forms and proportions. Water is being changed into invisible vapor from the ice and snow of the frozen north no less constantly, though less abundantly, than from the warm ocean waters of the tropics. As a result, the atmosphere is never free from the vapor of water. It may be present in small quantities only, as in the dry desert regions of the earth, or in the cold zones of the north and south, or in the rare and cold atmosphere of the mountain tops. The vapor capacity of a given space increases rapidly with increase in temperature. A cubic foot of vapor at a temperature of 50° F. at normal sea-level pressure, and at saturation, weighs about 4 grains; at 70° it weighs 8 grains; and at 100°, about 20 grains; hence with an increase in temperature from 50° to 70° the quantity of moisture at saturation is doubled.

The invisible vapor of water in the atmosphere is generally referred to as the *humidity* of the atmosphere. When the amount of vapor is actually weighed in grains, ounces, or pounds, or when it is measured in terms of pressure, as so many inches of mercury, it is referred to as *absolute* humidity. When it is measured in terms of percentage of the total amount which can exist in a given portion of the atmosphere, it is referred to as the *relative* humidity. For example, as stated above, the total quantity of invisible vapor which may be contained at ordinary pressure, in a cubic foot at 70° temperature, is 8 grains. The atmosphere is then said to be saturated, and the *relative* humidity is 100 per cent. Suppose the amount of vapor to be reduced to 4 grains, or one-half the full capacity, the temperature remaining the same, the percentage of

the *relative* humidity would then be 50. The point of saturation is also called the *dew point.*

As the temperature of the atmosphere diminishes rapidly from the earth's surface upward, the capacity for water vapor diminishes, and at a more rapid rate. Calculations have been made of the amounts of aqueous vapor which the atmosphere can hold in suspension at different temperatures and below given altitudes. In the following table by Ferrel, the figures given show the depth in inches of water which would result if all of the vapor which it is possible for the atmosphere to hold in suspension under the given conditions were condensed to water.

AMOUNT OF AQUEOUS VAPOR IN SATURATED ATMOSPHERE OF STATED TEMPERATURE AND DEPTH.

Elevation.	80° F.	70° F.	60° F.	50° F.
6,000 feet.	1.3 inch.	1.0 inch.	0.1 inch.	0.5 inch.
12,000	2.1	1.5	1.1	0.8
18,000	2.5	1.8	1.3	0.9
24,000	2.7	2.0	1.4	1.0
30,000	2.8	2.1	1.5	1.1

The conditions assumed probably never occur in nature, as the rapid decrease in temperature with elevation would preclude the possibility of an average temperature sufficiently high, or at uniform saturation, to the given elevations. Probably under the most favorable conditions of a moist atmosphere in the tropics, the amount of vapor from the earth's surface to the upper limits of the atmosphere, if condensed, would measure less than two inches.

The decrease in the amount of vapor in the atmosphere with decrease in temperature may be stated in another form. At the equator the amount of vapor may reach about 11 grains per cubic foot, or about 20 tons per cubic mile; at latitude of 40° it may reach about 5 grains or about 9 tons per cubic mile, assuming a temperature of 55° as an average for the year; at latitude 70° with an average temperature of 30°, it may attain about 2 grains per cubic foot, or about 3.5 tons per cubic mile. It has been estimated that one-half of the total quantity of vapor in the entire atmosphere lies below an elevation of about 6500 feet, or below the summit of Mt. Washington; hence the decrease in quantity is very rapid

and we may easily realize how mountains of moderate elevation, and even the higher hills, may affect the rainfall and cloudiness of a locality.

As the absolute humidity of the atmosphere at any given place depends upon the local temperature and a local water supply, there is a steady decrease in the amount of water vapor from the equator to the poles, from the surface of the earth upward, and from the oceans toward the interior of the continents. This general law of distribution may, however, be modified, and even completely reversed, by the direction and character of the wind movement over a given area. While the vapor of the atmosphere is taken up by evaporation from a variety of surfaces, such as lakes, rivers, moist fields, or the foliage of the forest, the great source of supply must always be the surface waters of the equatorial and tropical oceans. From these it is carried up by the winds and distributed to all parts of the globe.

This invisible moisture of the atmosphere has a most important function to perform in tempering the heat and cold. Where it is found in abundance, extremes of temperature are unlikely. Its absorbing power is great compared with that of dry air, and the earth's surface is protected against the heat of the sun by day, and the rapid cooling by radiation during the night. Its abundance in the tropics is largely responsible for maintaining the uniformly high temperature of those regions. Its absence in limited areas of the tropical and sub-tropical zones is marked by great diurnal fluctuations in temperature, as in the arid regions of the southwest. Most important of all, it is the great source of supply of the rainfall and snowfall of the world; without first passing into the form of vapor, the oceans and rivers would have but little effect in watering the fields and forests of the earth.

While the benefits of the atmospheric vapor are numerous and apparent, it may also be a source of much personal discomfort. When the relative humidity is high, that is, when the vapor is near the saturation point, or dew point, evaporation from the body becomes sluggish, or ceases, the air begins to feel muggy, when the temperature is high, or raw when it is low. A temperature which would be considered moderate with a dry air becomes oppressively hot when the humidity ap-

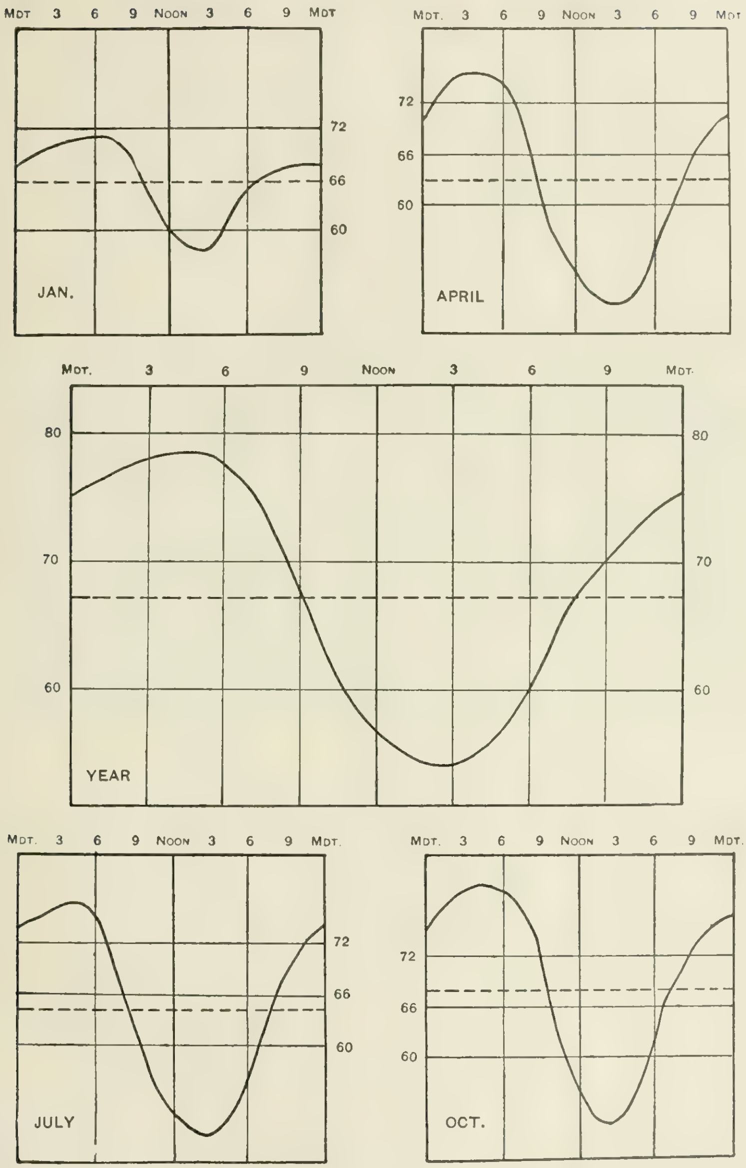


FIG. 39.—Mean Hourly Relative Humidity.

The mean hourly relative humidities for the months of January, April, July, October and for the year are expressed as percentages, complete saturation being represented by 100 per cent. The curves are based on the 30 months' record of a Richard hygrograph.

proaches or exceeds 80 per cent. On the other hand, a cold of 15° or 20° above zero with a humidity of 80 per cent, a condition which is common in the Atlantic coast states, will cause much suffering, while temperatures of 20° below zero in the northwest, with a humidity of 25 or 30 per cent, are described as comfortable and exhilarating.

The atmosphere does not lose in transparency with increasing humidity either relative or absolute; on the contrary, a high humidity is often accompanied by greater clearness, and an unusual transparency has come to be regarded as a sign of rain. When, however, the vapor reaches the dew point, just beyond the point of saturation, we have a series of phenomena of the highest interest and importance to us, resulting from condensation into the visible forms of dew, fog, clouds, rain, snow, frost and hail. The particular form of condensation is primarily a function of temperature, modified by local conditions of topography, elevation above the earth's surface, and the movements of the atmosphere.

Hourly Variations in Humidity.

Continuous automatic records of the variations of relative humidity are available for about two years and a half at Baltimore. While this is

TABLE XXXVI.—MEAN HOURLY RELATIVE HUMIDITY.

(1902–1904.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
1 A. M.	69	70	78	74	76	80	81	83	84	78	72	70	76
2	69	71	78	75	78	82	81	84	84	78	72	70	77
3	70	71	79	76	79	84	82	84	85	80	72	70	78
4	70	72	80	76	80	84	83	85	86	80	74	70	78
5	70	73	81	76	80	84	83	86	86	80	74	70	79
6	70	74	82	76	77	80	82	86	86	80	74	70	78
7	71	76	80	72	70	74	77	82	82	78	74	70	76
8	71	75	76	68	66	70	73	76	76	74	72	70	72
9	69	71	72	62	60	64	68	70	70	67	66	66	67
10	66	70	69	57	55	60	64	65	65	62	61	62	63
11	62	66	66	54	51	56	60	62	60	58	56	59	59
Noon	61	64	64	52	50	54	58	59	56	55	53	56	57
1 P. M.	59	62	60	50	47	52	57	57	56	54	50	54	55
2	58	60	60	49	46	52	56	56	56	52	50	54	54
3	58	58	60	48	46	52	55	56	56	52	51	55	54
4	60	59	60	49	48	53	57	58	57	54	52	56	55
5	62	60	60	51	50	54	60	60	60	58	56	59	58
6	64	62	61	52	54	56	62	62	64	63	60	61	60
7	66	64	66	58	60	62	67	68	71	68	62	63	65
8	68	66	69	61	64	66	71	72	74	71	65	64	68
9	68	67	72	64	68	70	75	77	78	74	66	66	70
10	68	68	73	67	71	74	77	79	80	75	68	66	72
11	67	70	76	69	73	76	79	81	82	76	70	68	74
Midnight	68	70	77	70	75	78	80	82	82	76	72	68	75
Average	66.2	67.4	70.6	62.6	63.4	67.4	70.4	72.1	72.4	68.5	64.3	64.0	67.4

a much shorter record than that utilized in the discussion of temperature, pressure, wind direction and other factors, it is still of sufficient length to enable us to establish firmly the form of the diurnal curve. The diurnal variation in the relative humidity is represented by a simple curve with its maximum point at about 5 a. m. for the year, but varying between 4 a. m. and 7 a. m. according to the season. The time of maximum follows closely the time of sunrise. The minimum point, or the dryest time of day, occurs between 1.30 p. m. and 3.30 p. m. The

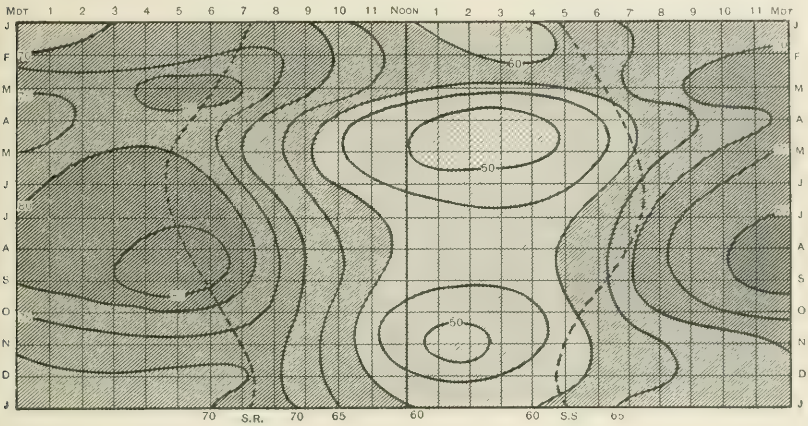


FIG. 40. Mean Hourly Relative Humidity.

As in Fig. 39, the hourly humidities are expressed as percentages, 100 per cent representing complete saturation. The light shades represent the lower humidities, or the dryer portions of the day and year; the heavy shades, the time of higher humidities. The dotted lines, S. R. and S.S indicate the time of sunrise and sunset respectively. The diagram is based on the 30 months' record of a Richard hygrograph.

details of the hourly variation are shown statistically in Table XXXVI, and graphically in Fig. 39 and Fig. 40. The seasonal distribution is revealed at a glance in Fig. 40, in which the light shades represent the lower humidities, or the dryer portions of the day, and increase in the density of the shades shows an increase in the humidity. It will be observed that the dotted line representing the time of sunrise (S. R.) passes through the areas of heaviest shading, approximately in their central portions. The values in both tables and figures are shown in percentages, total saturation of the atmosphere being represented by 100.

The actual values for relative humidity from hour to hour during the day fluctuate rapidly on days with unsettled weather. The changes are particularly marked during the course of a thunderstorm. There is frequently very little resemblance between the curve showing *actual* conditions and that representing *average* conditions for a month or more. Every change in the direction of the wind, or in the temperature, is reflected in the form of the actual curve. In Plate VIII some typical relative humidity curves made by the self-recording instrument are reproduced and they may thus be compared with the curve in Fig. 39 representing average values.

Direct observations of relative humidity were made at varying hours of the day from time to time in past years. The continuous record enables us to determine the corrections to be applied to any of the combinations of hours employed in the past in order to obtain a correct daily mean based on 24 hourly observations. A daily mean derived from any of the series of three observations per day, one in the morning between 7 and 9, one at 3 or 4 in the afternoon and the other between 9 and 11 at night, gives a value so nearly equal to the true mean based on 24 hourly observations that the corrections to be applied fall within the limits of probable error of observation, and hence may be neglected. For the series of observations made at 8 a. m. and 8 p. m. the departures from the true average are large enough to require the application of the necessary corrections shown in the following figures:

CORRECTIONS TO OBTAIN TRUE DAILY MEAN HUMIDITY.

(Expressed in percentages.)

Hours of observation.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
$\frac{(8\text{ a. m.} + 8\text{ p. m.})}{2}$	−3.3°	−3.1°	−1.9°	−1.9°	−1.6°	−0.6°	−1.6°	−1.9°	−2.6°	−4.0°	−4.2°	−3.0°	−2.6°

Phases of the Diurnal March of Relative Humidity.

The time of occurrence of the maximum and minimum values for the day, and the time, in hours and minutes, when the humidity is the same as the mean for the entire day, are shown in the following table and in Fig. 41:

PHASES OF THE DIURNAL MARCH OF RELATIVE HUMIDITY.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Max. (a. m.)	7.30	7.20	5.40	4.30	4.30	4.00	4.30	5.30	5.00	4.30	5.30	4.30	5.00
First mean (a. m.)	10.00	10.40	9.20	8.50	8.30	8.30	8.20	8.40	8.40	8.50	9.20	9.30	9.30
Min. (p. m.)	2.30	3.20	3.30	3.00	2.30	2.00	3.00	2.30	1.30	2.30	1.30	1.30	2.30
Second mean (p. m.)	7.00	9.00	8.40	8.40	7.50	8.20	7.50	8.00	7.20	7.20	7.40	8.00	7.50

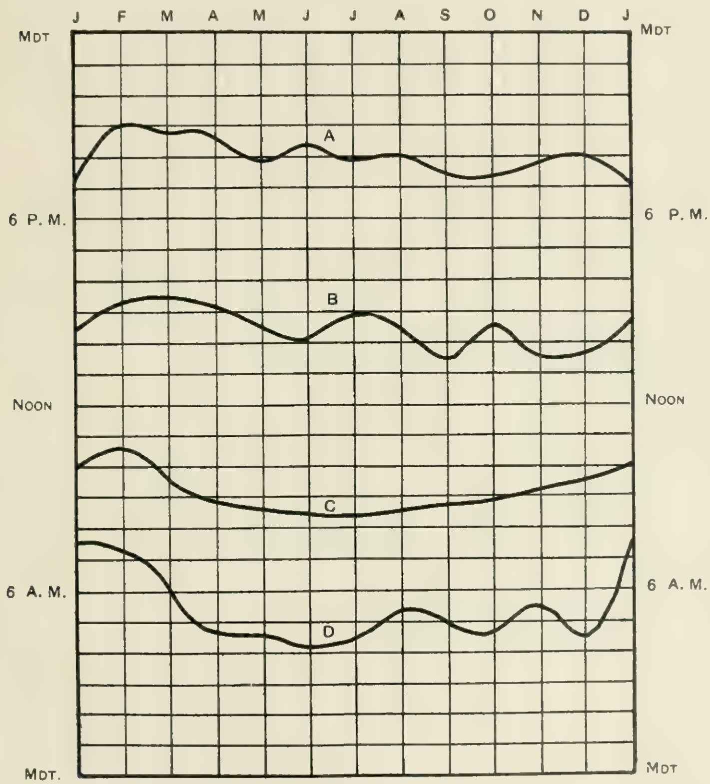


FIG. 41.—Phases of the Diurnal Variations in Relative Humidity.

B shows the variations in the hour of occurrence of the dryest time of the day from month to month; D the time of occurrence of the dampest portion of the day; A and C show, respectively, the afternoon and the morning hours when the mean humidity of the day is most likely to occur.

Mean Monthly and Annual Relative Humidity.

The observed values of the relative humidity for the entire period from 1871 to 1903 were reduced to true mean monthly and annual values based upon hourly observations; these corrected figures are contained

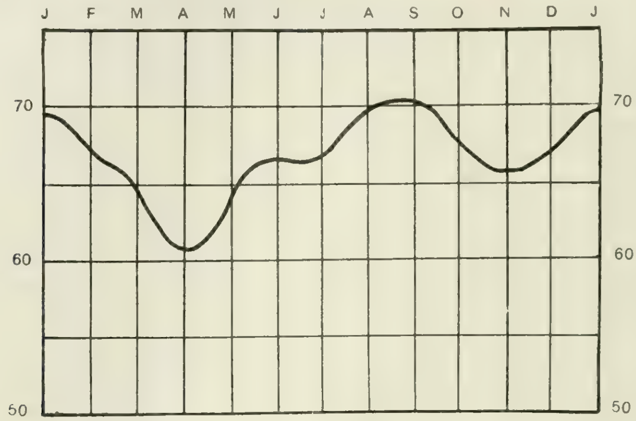


Fig. 42.—The Mean Monthly Relative Humidity.

The diagram is based on direct observations at two or three stated periods of the day during a period of 30 years; the average values were corrected for the diurnal variation, and expressed as percentages of total saturation.

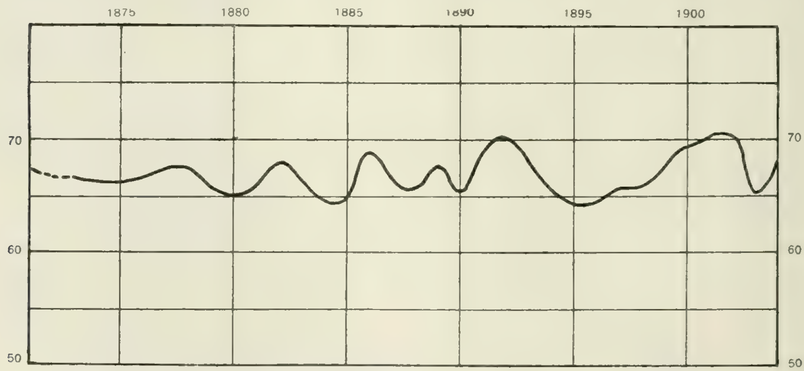


Fig. 43.—Variations in the Mean Annual Relative Humidity.

(Expressed as percentages of total saturation.)

in Table XXXVII, together with the ten-year monthly averages and the normals for the entire period. The monthly normals and the variations in annual means are also graphically shown in Fig. 42 and Fig. 43 respectively.

The normal amount of moisture in the atmosphere for the entire year is about two-thirds of the total capacity of the atmosphere for water vapor, namely, 66.5 per cent. The mean monthly amounts vary from season to season, being greatest in the month of September (70.4) and

TABLE XXXVII.—MEAN MONTHLY RELATIVE HUMIDITY.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
1871	68	66	82	66	66	68	65	69	65	66	65	63	67.4
1872	62	58	58	50	50	60	60	65	66	62	57	58	58.8
1873	66	60	54	59	65	64	63	78	76	72	69	71	66.1
1874	75	72	65	66	59	64	63	62	72	66	63	66	66.4
1875	73	68	68	60	51	63	65	75	66	67	66	74	66.3
1876	68	65	66	56	64	66	63	69	72	66	70	71	66.3
1877	74	66	70	65	64	67	68	62	71	71	68	66	67.7
1878	72	68	64	64	63	64	66	72	72	66	67	68	67.2
1879	71	70	64	57	58	64	61	70	70	68	63	69	65.4
1880	73	66	62	55	58	62	64	71	67	67	66	69	65.0
1881	71	66	62	59	66	69	61	60	68	67	67	70	65.5
1882	74	66	63	60	70	60	66	74	74	75	65	65	67.7
1883	74	66	56	65	59	68	67	63	70	72	64	67	65.9
1884	67	68	66	57	59	66	65	69	63	64	61	68	64.4
1885	65	63	56	56	65	62	63	69	67	75	69	62	64.3
1886	75	69	62	69	71	71	72	71	70	66	61	71	69.0
1887	69	71	60	59	68	66	71	70	70	64	60	68	66.3
1888	67	68	64	51	68	64	66	68	74	65	67	62	65.3
1889	67	61	61	63	66	72	73	70	75	64	71	67	67.5
1890	66	70	64	60	67	64	62	70	74	68	62	62	65.8
1891	67	69	70	55	59	71	77	78	78	71	70	67	69.3
1892	76	75	71	63	68	76	71	72	69	63	71	71	70.5
1893	72	69	65	68	66	73	65	65	67	71	68	68	68.1
1894	69	67	61	58	67	66	64	68	73	67	60	68	65.7
1895	70	58	60	62	66	69	64	64	67	52	70	68	64.2
1896	63	65	59	62	66	69	68	63	66	62	65	62	64.2
1897	66	71	63	55	60	64	70	68	65	70	66	72	65.8
1898	70	62	67	57	68	61	66	72	65	69	67	66	65.8
1899	66	72	72	61	63	67	68	70	69	71	67	64	67.5
1900	71	68	66	59	59	71	62	68	83	80	72	72	69.2
1901	69	59	73	63	72	68	74	75	74	66	66	77	69.7
1902	70	72	76	68	64	65	72	69	75	74	72	70	70.1
1903	66	62	73	54	65	75	65	76	70	63	56	57	65.2
Average, 1871-80	70.2	65.9	65.3	59.8	59.8	64.2	63.8	69.3	69.7	67.1	65.4	67.5	65.7
1881-90	69.5	66.8	61.4	59.9	65.9	66.2	66.6	68.4	70.5	68.0	64.7	66.2	66.2
1891-1900	69.0	67.6	65.4	60.0	64.2	68.7	67.5	68.8	70.2	67.6	67.6	67.8	67.0
1871-1903	69.5	66.5	64.9	60.1	63.6	66.6	66.4	69.2	70.4	67.6	65.8	67.2	66.5

least in the month of April (60.1). For individual years, the monthly averages vary considerably. For example, the average humidity for the month of March has been as high as 82 per cent and as low as 54 per cent, a range of 28. A similar range has been experienced in the month of October. The month possessing the smallest range in the monthly

average value is January, with a maximum of 76 per cent and a minimum of 62 per cent, a range of 14.

The range in actual conditions of humidity, as distinguished from average conditions for a considerable period, shows, of course, much greater fluctuations. As the upper limit, namely, 100 per cent, is reached at all seasons of the year during misty or rainy weather, the lower limit is the index of variability. The lowest values are most likely to occur during the clear, cold days of winter or early spring. During the two years and a half in which continuous automatic registration was maintained at Baltimore, the humidity during the afternoon hours occasionally fell to 25 per cent, or one-fourth the moisture capacity. The occasions upon which the moisture content fell below this percentage were rare. A few of the exceptionally dry days during this period are here cited:

EXCEPTIONALLY DRY DAYS.

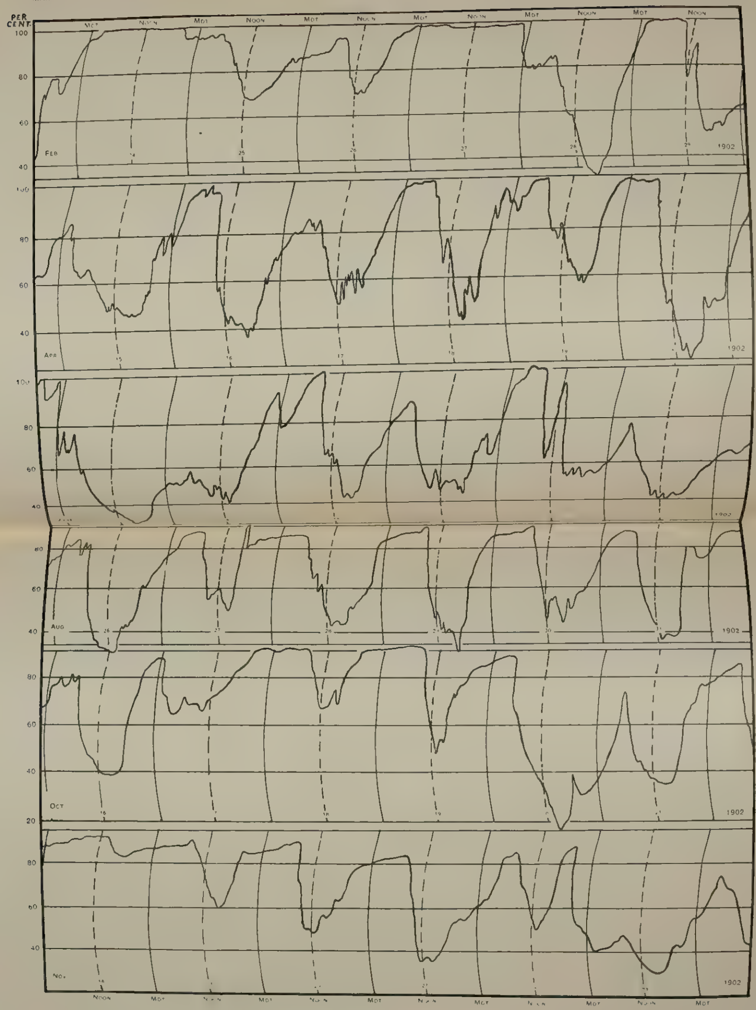
January 31, 1903,	minimum	humidity	was	20	per cent.
April 5, 1904,	"	"	"	11	" "
May 4, 1904,	"	"	"	15	" "
August 17, 1902,	"	"	"	24	" "
October 30, 1903,	"	"	"	14	" "
November 9, 1902,	"	"	"	22	" "

The limits of variability in the annual average humidity during 33 years were 70.5 per cent in 1892, and 58.8 per cent in 1872, a range of 11.7 per cent. The ten-year averages have only varied from the normal for the entire period by the following small departures:

1871 to 1880........................0.8 below normal;
1881 to 1890........................0.3 below normal;
1891 to 1900........................0.5 above normal.

Absolute Humidity.

Expressing the humidity in the terms of the actual weight of the water vapor in the atmosphere at different hours of the day throughout the year, the distribution is shown in the following table. These figures show the average amount of water present in the atmosphere at the hours specified during the five years from August, 1881, to July, 1886. As the amount of moisture in the atmosphere is primarily a function of the temperature of the air, we find a steady increase in the *absolute*



SELECTED RELATIVE HUMIDITY CURVES

humidity from January, the coldest month, to July, the warmest month of the year.

MEAN ABSOLUTE HUMIDITY.

(Weight of the vapor of water in grains per cubic foot.)

Hours of Observation	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
7 a. m	1.41	1.58	1.78	2.72	3.89	5.56	6.50	5.98	5.29	3.83	2.26	1.74	3.082
11 a. m.	1.47	1.66	1.78	2.71	3.80	5.50	6.12	6.06	5.53	3.87	2.36	1.82	3.222
3 p. m	1.60	1.71	1.84	2.78	4.02	5.51	6.11	6.16	5.48	4.06	2.49	1.91	3.267
7 p. m	1.57	1.72	1.91	3.01	4.20	5.79	6.68	6.38	5.79	3.96	2.47	1.88	3.437
11 p. m	1.54	1.72	1.82	2.93	4.08	5.82	6.71	6.38	5.61	4.03	2.48	1.83	3.327
Average	1.519	1.678	1.827	2.828	3.997	5.639	6.425	6.193	5.539	3.951	2.411	1.836	3.267

Mean Vapor Pressure.

The average monthly values of the tension of the vapor of water in the atmosphere, based upon observations of temperature of the air and the temperature of the wet-bulb thermometer at 8 a. m. and 8 p. m. from 1892 to 1903, are shown in the following table expressed in fractions of an inch of mercury:

Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
.136	.133	.193	.252	.394	.549	.631	.614	.512	.334	.222	.152	.344

PRECIPITATION.

Introduction.

The German meteorologist, Dové, has aptly compared the atmosphere to a huge still, of which the sun is the furnace, and the sea the boiler, while the cold air of the higher elevations and of the temperate zones plays the part of the condenser; we, on a wet day, catch some of the liquid which distills over.

The condition and method of formation of dew, fog, cloud, rain, snow and hail are admirably and concisely stated in the following extract from one of Dr. Hann's recent treatises:[1]

[1] Hann, J. Allgemeine Erdkunde. I. Abtheilung. 8° Wien, 1896, pp. 173 *et seq.*

"Condensation of moisture gives rise to numerous phenomena which are collectively called hydrometeors. It takes place whenever the temperature falls below the dew point. Hence whatever favors a lowering of the temperature of the air favors the production of dew, fog, cloud, rain, snow and hail.

"The ground cooling rapidly during a clear, calm night by radiation, lowers the temperature of the air resting upon it; we then have dew. With a temperature below freezing we will have frost. Warm, moist air mixing with colder air near the earth's surface will give us fog; thus we see fog formed over rivers in the early morning. Over the Banks of New Foundland we have a cold body of water over which pass warm, moist southerly winds, producing almost continual fog. With a temperature below freezing point the fog collects on trees and shrubs in the form of hoar frost. Mixing of air currents at different temperatures high above the earth, and rising and cooling moist air, produce clouds. Fog and clouds are composed of small drops of water. In winter and at high altitudes they are composed of ice crystals. High cirrus clouds all the year round are composed of ice crystals. At an elevation of 3500 meters (11,483 feet) in the middle latitudes the air temperature is below the freezing point throughout the year. The presence of ice crystals in the higher clouds is shown by the colored rings about the sun and moon. These ice crystals and drops of water float in the air because of the great amount of surface exposed to the resistance of the air in comparison with their weight.

"As fog and cloud increase in density the drops coalesce and become larger, until they become too large and heavy to be supported by the resistance of the air; they then go over into rain. Should the rain pass through drier strata of atmosphere it may be reabsorbed. In winter condensed water crystallizes and falls as snow. In stormy weather and a temperature near freezing, the snow packs and balls and falls as snow pellets. As these become firmer and pass alternately through layers of air above and below freezing point they become coated with water in the warmer layer and with ice in the colder layer, and thus form hail.

"With an increasing quantity of vapor in the atmosphere the entire

heavens become of a whitish dimness and lunar or solar halos appear. In most cases, however, the condensed vapor is not uniformly distributed in the atmosphere, but is collected in masses which float in the air, reflecting the light and throwing shadows. We then call them clouds."

The Causes of Precipitation.

The theory that rainfall is primarily a result of the mixing of moist air currents at different temperatures has lost much in favor among meteorologists of to-day. Calculations have shown that the rain resulting from such a cause must be comparatively light, and would not at all account for the abundant precipitation of the tropics, or the heavy falls connected with the movement of storms. Clouds may undoubtedly be accounted for upon the supposition of a mixture of air currents, with high humidity, especially the stratified forms, but even here it is necessary to find a more abundant source of condensation. This is found in the agency of a rising current of air. As already stated, the atmosphere contains at all times a considerable amount of moisture, especially in the lower layers of the warmer climates. Conditions are favorable for an upward movement of the air wherever there are opposing currents or where there is a considerable difference in temperature over adjacent areas. Such conditions are always present within storm areas, or, on a larger scale, in the equatorial region where we have the northeast and southeast trades meeting and causing a slow upward movement of the atmosphere at all times. Rising currents with the attendant decrease in temperature, combined with the presence of moisture, are capable of accounting for the heaviest rainfalls recorded.

The Geographical Distribution of Rainfall.

The rainfall of a locality being primarily dependent upon the quantity of moisture in the atmosphere, that is, the *absolute* humidity, and this being in turn dependent upon the temperature, we find a steady decrease in the amount of precipitation from the equator to the poles. In the equatorial regions the annual rainfall averages about 75 inches, while within the Arctic circle it is reduced to less than 10 inches. The decrease

is not at all uniform, as other factors enter into the problem of distribution to such an extent as to overbalance the effect of the temperature. The prevailing distribution of atmospheric pressure, the prevailing wind direction, and topography, may separately or in combination be the determining factors in the distribution of rainfall over any given area.

The Influence of Wind Direction.

The effect of wind direction may readily be inferred from what has already been stated concerning the sources of atmospheric moisture. The oceans being the great source of supply, and the winds being the carriers and distributors of moisture, it follows that rainfall is most copious along the coasts, and decreases with distance from the coasts when the wind direction is from the oceans inland. In the United States there is a steady decrease from the Gulf and Atlantic coasts toward the central portions of the continent, being 50 inches to 60 inches in the southeast, and about 15 inches in the Rocky Mountain region. On the Pacific coast a similar decrease obtains but is here greatly modified by the presence of high mountain ranges near the coast. The same is true in a general way over all of the continental areas.

The Influence of Topography.

The distribution of rainfall along the Pacific coast from California northward affords an excellent illustration of the influence of mountain ranges crossing the path of rain-bearing winds. During the rainy season the moist and comparatively warm winds from the Pacific are first forced up over the Coast Range and again over the Sierra Nevadas to altitudes varying from a few thousand to over ten thousand feet. The moisture is cooled below the saturation point and rains are copious. The winds descend upon the eastern slope of the Sierra Nevada Mountains comparatively dry. While the annual rainfall on the Pacific coast decreases from about 50 inches to 10 inches in passing over a distance of about two hundred miles inland, a similar decrease from the Atlantic and Gulf coasts extends over 1500 to 2000 miles.

In northern India the elevated range of the Himalaya Mountains lies

directly in the path of the southwest monsoon winds. The winds, blowing for days over the warm waters of the Indian Ocean, reach the mountains heavily laden with moisture, and are forced up the southern slope to elevations of 20,000 feet and more before they can proceed further on their way to the deep and persistent barometric depression which is centered to the north of the mountains during the warm season. Among the foothills on the southern slope of the mountains, just north of Calcutta, and at an elevation of about 4500 feet, lies the station of Cherra Poongee, which has the heaviest annual rainfall in the world. The average annual fall for 25 years approximates 475 inches; the annual amount has varied from about 300 inches to over 900 inches, nearly all of which falls in the six months from April to September.

The Influence of Atmospheric Pressure.

As previously pointed out, conditions which favor the production of rising air currents are favorable to the production of rain. Areas over which the barometer is relatively high are apt to be poor in rainfall, and areas with a low barometer in comparison with adjacent areas are apt to be comparatively rich in rainfall, other conditions being equal. This broad generalization may be verified by almost any daily weather chart which may be consulted, and is familiar to all who have occasion to study the weather charts issued by the United States Weather Bureau, or those of any other nation issuing such charts. When we see upon these charts an enclosed area of low barometer, or a "Low," as it is familiarly called, cloudiness and rain prevail within this area; where the barometer is high, relatively, the skies are prevailingly clear or partly clouded. "High area" weather is proverbially "fine" weather; "low area" weather is generally "bad" weather. As the winds flow toward the center of an area of low barometer from all sides, the air at and near the center must necessarily rise, and rising, it is cooled. If it rises high enough, cloud formation and rain follow. On the other hand, where the barometer is relatively high, the air descends and the winds blow out from the central portions of the high area in all directions. We have seen that ascending air is cooled by expansion and radiation as it rises;

conversely, descending air is warmed by compression. As it warms, its capacity for moisture increases, and not having an opportunity to take up more moisture in its descent, it becomes relatively drier; its *relative* humidity is decreased. Clouds which may be within this area at the beginning of its formation tend to dissolve, and near the center where the descent of air is most active, the skies are apt to be clear. These areas of low and high pressure (cyclones and anticyclones as they are technically termed) move from west to east in rapid succession in the middle latitudes and constitute the distinguishing feature of our weather.

In equatorial regions there is a belt of varying width in which the pressure is constantly lower than it is to the north or south. Within this belt, situated between the northeast and southeast trade winds, the air has, in addition to its westward drift, an upward movement, producing the "cloud belt" or doldrums with its almost daily copious showers. To the north of the northeast trades and south of the southeast trades there are broad belts, most regularly developed over the southern hemisphere where the surface conditions are more uniform, in which the pressure is relatively high. Here the air has a descending tendency and these areas are characteristically dry. Within them are the great desert regions of the globe—the Sahara, the Arabian desert, the arid regions of Australia, as well as those of our own Southwest. Over the oceans they are known as the "horse latitudes" with their light winds and scanty rainfall.

The Seasonable Distribution of Rainfall.

Climates are often classified according to the manner in which the rainfall is distributed through the year. We have regions of perennial rainfall, as in the United States east of the Mississippi River, where there is a fairly uniform precipitation throughout the year. This is a condition which prevails with limited exceptions between latitudes 35° and 60°. Within the tropics, and over limited areas elsewhere, as in the upper Missouri Valley, there are large areas in which most of the annual fall of rain occurs in the summer months, with light rain in winter and spring. In other regions, as in the Pacific coast states, nearly all of the precipitation occurs in the winter months with little or no rain in sum-

mer. Lastly there are the arid regions of the world which are nearly free from rain throughout the year.

Hourly Amount of Rainfall.

A diurnal period in the relative amounts and frequency of rainfall is most distinctly revealed in tropical countries, but is still clearly shown in the summer months of the middle latitudes. The precipitation which occurs in connection with the movement of a general barometric depression has a fairly uniform distribution throughout the day; that occurring in connection with thunderstorms is restricted mostly to the afternoon hours, and is intimately associated with the diurnal variation in temperature and pressure.

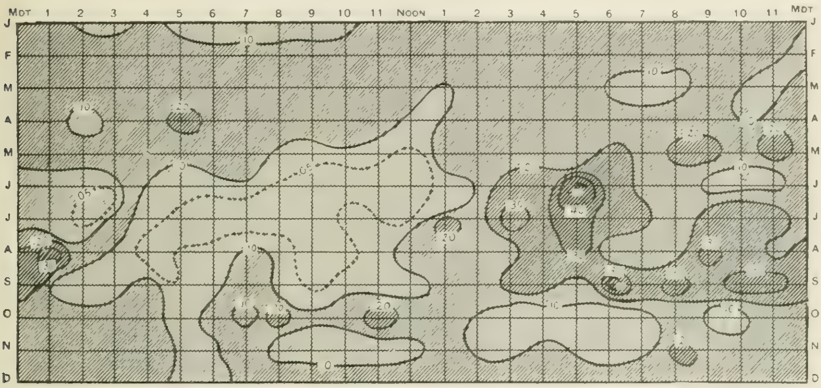


Fig. 44.—Average Hourly Precipitation.

The average amount of rainfall or snowfall during each hour of the day, for every month of the year, is shown by the heavy black lines and the shaded areas. The light shades show the time of day and year when the precipitation is usually lightest. The figures attached to the curved lines show the amount of the precipitation in hundredths of an inch. The values are based on the ten years' record of a tipping-bucket raingage and on eye observations. Only days with an appreciable amount of precipitation were considered in determining the average amount of precipitation for the day.

The most conspicuous feature of the diagram representing the hourly quantity of rainfall (see Fig. 44) is the uniform distribution of the precipitation throughout the day during the winter and spring months. This is doubtless explained by the fact that the winter and spring snows and rains occur in connection with the more or less regular succession of

the cyclonic disturbances of the middle latitudes whose eastward progress is but slightly, if at all, affected by the diurnal variations of temperature and pressure. On the other hand, the intensity of summer rains has a distinct diurnal period, being light in the forenoon, increasing rapidly to noon, or 1 p. m., and then more slowly to a maximum at about

TABLE XXXVIII.—TOTAL HOURLY RAINFALL PER MONTH AND YEAR.

(In hundredths of an inch.)

Hours.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Sums	Means
Md't. to 1 A. M.	.11	.16	.16	.11	.11	.08	.09	.35	.10	.15	.17	.11	1.70	.14
1 " 2 "	.09	.13	.18	.09	.18	.06	.03	.12	.06	.15	.15	.14	1.38	.12
2 " 3 "	.09	.11	.16	.15	.16	.05	.12	.10	.09	.15	.13	.09	1.40	.12
3 " 4 "	.11	.11	.13	.15	.12	.06	.08	.02	.16	.14	.12	.12	1.32	.11
4 " 5 "	.06	.13	.13	.20	.11	.06	.03	.06	.05	.09	.10	.08	1.10	.09
5 " 6 "	.08	.16	.13	.17	.12	.06	.04	.07	.09	.16	.09	.07	1.24	.10
6 " 7 "	.07	.14	.15	.13	.12	.10	.05	.10	.11	.09	.12	.11	1.29	.11
7 " 8 "	.08	.15	.12	.17	.09	.04	.04	.08	.06	.20	.08	.15	1.26	.10
8 " 9 "	.07	.18	.13	.14	.08	.04	.04	.04	.04	.10	.07	.14	1.07	.09
9 " 10 "	.10	.22	.13	.14	.10	.02	.08	.02	.08	.11	.10	.15	1.25	.10
10 " 11 "	.13	.17	.11	.12	.07	.05	.06	.08	.08	.20	.08	.16	1.31	.11
11 " Noon	.12	.14	.12	.10	.05	.05	.04	.28	.08	.15	.07	.15	1.35	.11
Noon " 1 P. M.	.15	.14	.10	.11	.13	.08	.21	.17	.15	.14	.11	.15	1.64	.14
1 " 2 "	.16	.14	.12	.14	.19	.10	.16	.13	.17	.10	.10	.14	1.65	.14
2 " 3 "	.12	.12	.13	.12	.16	.23	.36	.18	.24	.08	.10	.14	1.98	.16
3 " 4 "	.11	.13	.19	.15	.12	.22	.22	.26	.27	.09	.18	.14	2.08	.17
4 " 5 "	.11	.15	.12	.18	.12	.52	.31	.34	.14	.09	.09	.13	2.30	.19
5 " 6 "	.12	.16	.10	.14	.24	.24	.22	.10	.40	.06	.08	.14	2.00	.17
6 " 7 "	.12	.17	.08	.13	.17	.18	.25	.18	.28	.08	.07	.15	1.86	.16
7 " 8 "	.12	.16	.08	.13	.27	.14	.17	.11	.37	.15	.23	.15	2.08	.17
8 " 9 "	.12	.15	.12	.12	.23	.06	.27	.30	.26	.09	.15	.18	2.05	.17
9 " 10 "	.15	.13	.10	.10	.18	.06	.21	.22	.32	.10	.14	.14	1.85	.15
10 " 11 "	.13	.12	.09	.16	.26	.09	.24	.12	.33	.15	.15	.14	1.98	.16
11 " Md't.	.10	.10	.15	.14	.13	.14	.13	.21	.26	.18	.14	.13	1.81	.15

Table XXVIII. Total hourly precipitation per month and year. The figures expressing hundredths of an inch of rainfall or melted snow, indicate the amount of precipitation which was recorded on an average per month and year during each hour of the day. For example, an average of 10 hundredths of an inch of rain fell from noon to 1 p. m. during the month of March from 1893 to 1902; 21 hundredths in July, and 164 hundredths on the average per year during that hour. The figures are based upon the ten years' record of a self-recording rain gage.

5 p. m., then decreasing to midnight or early morning. The influence of the thunderstorm is distinctly seen in this distribution of rainfall. The intimate connection existing between the intensity of rainfall and the occurrence of thunderstorms becomes strikingly apparent when Fig. 44, showing the hourly distribution of rainfall throughout the year, is compared with Fig. 77, showing the hourly distribution of

thunderstorms. The great majority of these local storms fall within the period from 2 p. m. to 8 p. m. in June, July and August.

The early morning hours of June, July and August have the smallest amount of rainfall (see Table XXXVIII), while the hours from 3 p. m. to 7 p. m. of the same months show the heaviest average falls. For the month of September the heaviest rains are apt to occur somewhat later in the day, between 6 p. m. and 11 p. m.

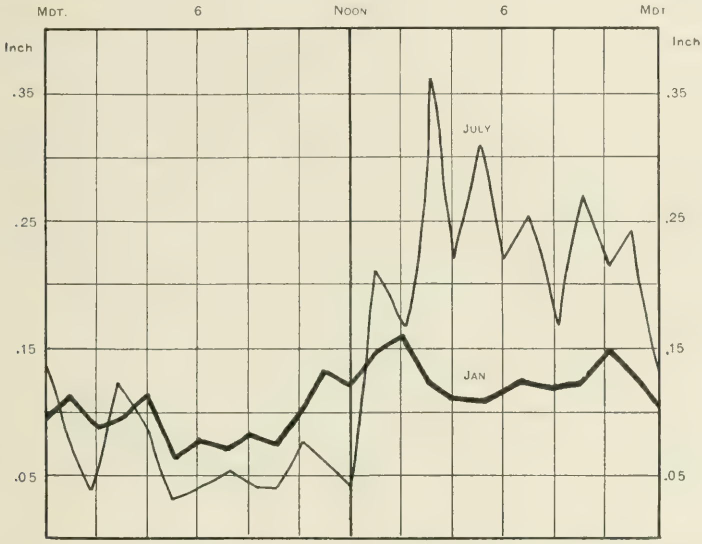


FIG. 45.—Average Hourly Amounts of Precipitation in January and July. The amounts are expressed in hundredths of an inch. In obtaining the mean amounts only such days were considered upon which rain fell to the amount of .01 inch or more.

In Fig. 45 the average monthly amount of rainfall for each hour of the day is shown graphically for the months of January and July. The comparatively uniform distribution throughout the day in January is in striking contrast with the small rainfall in the morning hours, and the rapid increase in the early afternoon hours in July.

HOURLY RAINFALL FREQUENCY.

The graphical record of rainfall during a period of ten years at Baltimore, together with a careful record of direct observations of beginnings

and endings of rainfall and snowfall, enable us to make a careful study of the actual and relative frequency of precipitation at different hours of the day and night. A table was prepared (see Table XXXIX) showing the number of times precipitation was recorded during each hour of the day from January, 1893, to the close of December, 1902.

TABLE XXXIX.—AVERAGE MONTHLY FREQUENCY OF RAINFALL FOR EACH HOUR OF THE DAY.

Hours.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Means	Ann'l sums
Md't. to 1 A. M.	3.1	4.3	4.0	3.8	3.2	2.0	2.8	1.7	2.4	3.0	3.8	3.0	3.1	37.1
1 " 2 "	3.0	3.7	3.7	3.5	3.7	1.9	2.4	1.6	1.6	3.0	3.8	3.0	2.9	34.9
2 " 3 "	3.0	3.5	3.6	3.5	3.4	1.7	2.1	1.3	1.3	2.9	3.6	2.6	2.7	32.5
3 " 4 "	3.3	3.8	3.9	3.4	3.6	1.8	1.9	1.3	1.3	2.8	3.4	2.9	2.8	33.4
4 " 5 "	3.2	4.1	3.8	3.8	4.1	1.7	1.8	0.9	1.4	2.5	3.4	3.3	2.8	34.0
5 " 6 "	3.6	4.3	4.6	4.7	4.2	1.6	1.9	1.8	1.8	3.0	3.7	3.3	3.2	38.5
6 " 7 "	3.7	4.3	5.2	4.6	4.8	2.0	1.8	1.8	2.2	3.2	3.5	3.3	3.4	40.4
7 " 8 "	4.4	5.4	5.7	5.5	5.0	2.9	2.4	2.8	2.5	4.1	3.7	4.2	4.0	48.6
8 " 9 "	5.4	5.6	5.4	4.6	5.5	2.5	2.9	2.4	2.9	3.9	4.1	4.6	4.2	49.8
9 " 10 "	5.4	5.3	5.2	4.5	3.9	2.2	2.6	1.7	2.3	3.5	4.5	4.4	3.8	45.5
10 " 11 "	4.8	4.4	5.1	4.5	3.8	2.3	2.8	1.9	2.7	3.5	4.3	4.2	3.7	44.3
11 " Noon	5.5	4.6	5.3	3.6	3.9	2.7	3.3	3.0	2.6	3.3	4.1	4.3	3.8	46.2
Noon " 1 P. M.	5.7	4.6	5.2	4.4	3.9	3.1	3.3	2.4	2.7	3.0	4.5	4.3	3.9	47.1
1 " 2 "	5.0	4.2	5.1	4.3	4.0	3.1	3.5	2.5	3.0	2.8	4.9	4.2	3.9	46.6
2 " 3 "	4.7	3.9	5.4	5.0	3.8	3.1	3.5	2.5	3.2	3.0	4.2	4.1	3.9	46.4
3 " 4 "	4.7	4.3	5.3	5.2	4.2	3.5	3.0	3.1	3.5	2.8	3.9	4.3	4.0	47.8
4 " 5 "	5.7	4.7	6.1	4.6	5.0	4.8	4.4	2.6	4.1	3.7	4.0	3.9	4.5	53.6
5 " 6 "	5.0	4.3	6.0	4.9	4.7	3.7	4.2	2.3	4.0	3.2	4.6	3.9	4.2	50.8
6 " 7 "	5.2	5.1	5.0	4.8	5.3	4.1	4.4	2.9	3.3	3.2	4.4	4.7	4.4	52.4
7 " 8 "	5.4	5.1	5.2	4.8	5.4	4.1	5.0	2.7	3.3	3.6	3.9	4.7	4.4	53.2
8 " 9 "	5.4	4.7	5.3	4.2	5.6	3.4	4.8	2.7	3.4	3.0	4.2	4.5	4.3	51.2
9 " 10 "	5.1	4.8	5.2	4.6	4.5	3.0	3.3	3.2	2.8	3.0	4.3	4.2	4.0	48.0
10 " 11 "	5.3	5.2	5.3	5.2	3.9	2.3	3.5	2.7	3.0	3.1	4.5	4.1	4.0	48.1
11 " Md't.	4.9	5.1	4.9	4.8	3.8	2.3	3.2	2.0	2.7	3.0	4.0	3.5	3.7	44.2

Table XXXIX. Average monthly and annual frequency of precipitation for each hour of the day. The figures indicate the average number of times rain or snow fell per month and year during each hour of the day. The results are based on the record of a self-registering rain gage for ten years, from 1893 to 1902.

The distribution of precipitation throughout the day is quite uniform. During the period of ten years there were but few months in which rain or snow was not recorded at all hours of the day at least once. Precipitation has most frequently occurred between 4 p. m. and 5 p. m. in the month of March, namely, 61 times in 10 years. The hour of least frequency is from 4 a. m. to 5 a. m. in the month of August, with a total number of 9 times in 10 years. On the average there is a fairly well

defined diurnal period in the frequency of precipitation. Beginning with a minimum in the early morning hours there is a rise in the average annual frequency to a maximum at about 5 p. m., followed by a return to the minimum in the early morning. This periodic movement is most readily seen in the July curve (see Fig. 46). In this month the minimum frequency (1.8) occurs at about 6 a. m. and the maximum (5.0) at 8 p. m. There is a comparatively rapid increase in frequency between 7 a. m. and 9 a. m., especially in the winter months. The most uniform

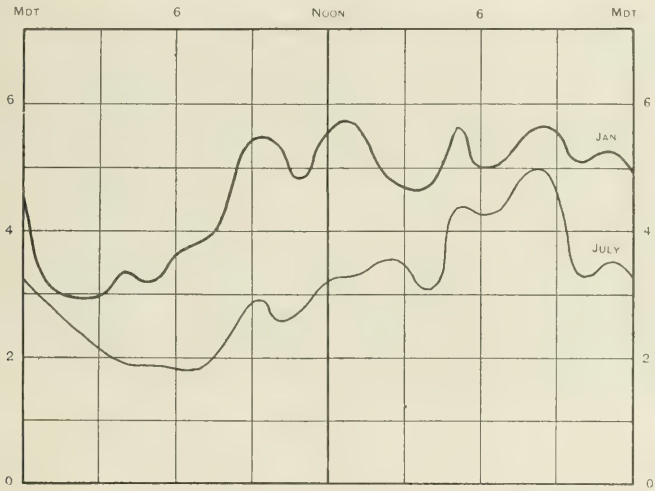


Fig. 46.—Average Hourly Frequency of Precipitation.

The curves show the average frequency, for each hour during the months of January and July, of the occurrence of precipitation to the extent of .01 inch or more. The values are based on the ten years' record of a tipping-bucket raingage, supplemented by eye observations.

distribution occurs during the cold months when the rains and snows are associated with the regularly recurring cyclonic disturbances. In the summer months the diminished effect of cyclonic disturbances is particularly noticeable in the reduced frequency of early morning rains, while the increasing afternoon rains are due to the summer thunderstorms, which reach a maximum frequency between 3 p. m. and 5 p. m.

The month of March exhibits the most uniform hourly distribution of

precipitation frequency, especially from about 7 a. m. until midnight. Precipitation is more frequent at all hours of the day during the winter and spring months than during the summer months. In Fig. 46 the January curve of frequency is well above the July curve throughout the day. This seasonal and diurnal distribution of precipitation frequency is graphically shown in Fig. 47, in which an increase in the intensity of shading represents an increase in the frequency of rains or snows. The figures attached to the heavy black lines show the average frequency

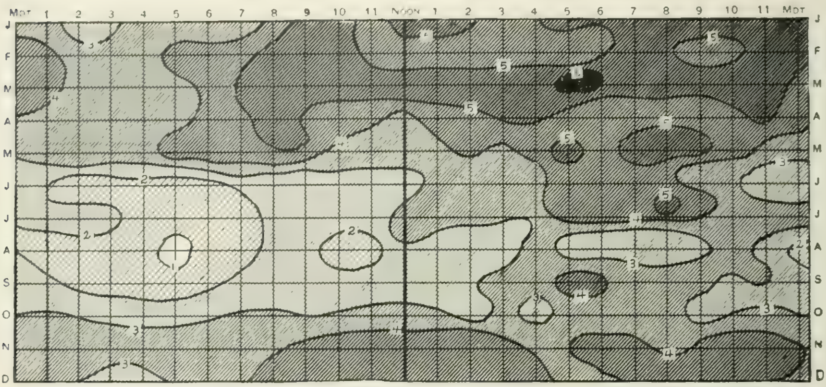


Fig. 47.—Average Hourly Frequency of Precipitation.

The heavy shades show the time of most frequent occurrence of precipitation during the day for every month of the year. The small figures attached to the irregular curved lines show the average number of times precipitation was recorded per month at the times indicated.

of occurrence per month for each hour of the day and month of the year. The hourly and seasonal distribution is shown more accurately in Table XXXIX, in which the average frequency is recorded to tenths for all hours and months of the entire year.

Duration of Precipitation.

Precipitation is not as continuous as it is generally supposed to be. If an automatic record of a rainy day be carefully examined, it will be found to be made up of numerous showers, some of them perhaps extending over an hour or two, but most of them lasting less than half an hour. The

duration and continuity depend mostly upon the position of the locality with reference to the center of the cyclonic disturbance which is the occasion of the precipitation. As the character of the storm and the position of its path depend largely upon the season of the year, the duration of the accompanying precipitation is found to vary with the season.

An automatic tipping-bucket rain gage has been in use at the Baltimore office of the Weather Bureau since January, 1893. The ten years' record enables us to obtain accurate values for the duration of the precipitation. These records were supplemented by direct observations during the daytime. In a later chapter of this report some attention will be devoted to an analysis of the character of the rainfall accompanying different types of storms. In the table below an effort has been made to arrive at average values only for storms of all kinds. It has been found desirable to compute the average duration for three different conditions. The first line of figures of the following table includes "traces" of rainfall, *i. e.*, amounts perceptible but too small to measure accurately by the ordinary methods. In the second line, only rains of measurable amounts have been considered, or precipitations equalling or exceeding one-hundredth of an inch in depth. The third line relates only to precipitations which amounted to less than one-hundredth of an inch, or to "traces."

AVERAGE DURATION OF PRECIPITATION.

(In hours and minutes.)

Class.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
A. Including "traces."	10.00	13.10	10.20	11.00	7.30	4.30	4.00	4.00	6.30	8.30	10.50	10.00	8.20
B. Excluding "traces."	11.10	13.10	8.45	11.00	7.00	3.30	4.00	3.30	5.15	8.05	9.25	9.20	7.50
C. Traces only.	3.15	3.00	3.20	4.05	3.00	2.10	1.40	1.40	2.30	3.45	3.45	2.55	3.00

Class A contains what may be regarded as the most trustworthy figures for the average duration of precipitation, as these averages express the entire period of precipitation in connection with a passing storm. The

rains of the winter, spring and autumn months show the influence of the more frequent cyclonic storms, while the rains of the summer months

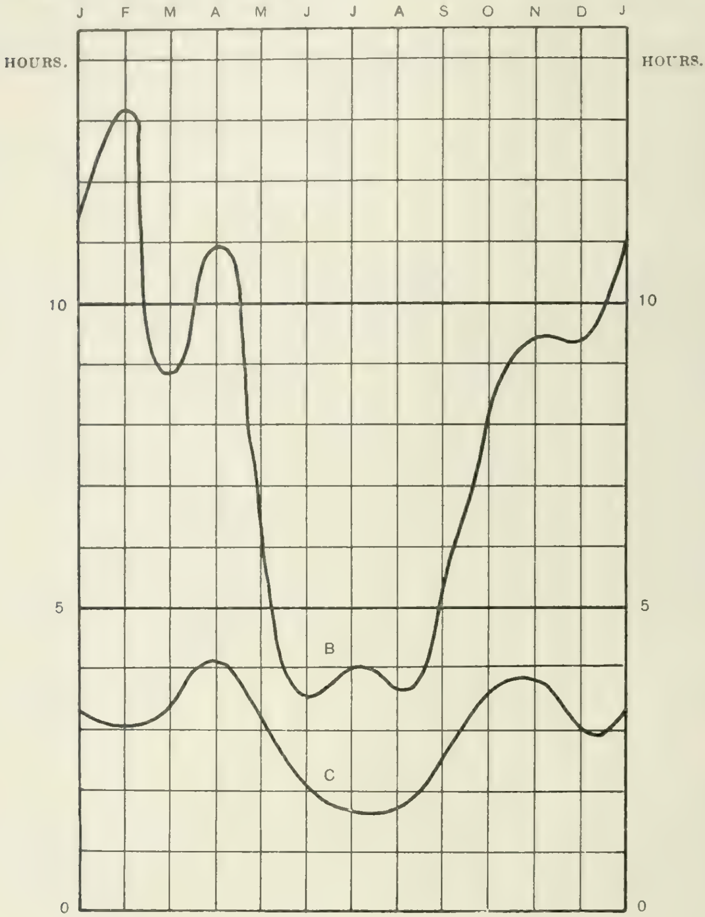


FIG. 48.—The Average Duration of Precipitation.

The upper curve (B) shows the variation in the average duration of rain and snow storms during which the precipitation amounted to .01 inch or more. The duration is expressed in hours and tenths of an hour; the values are based upon a ten years' record of a tipping-bucket raingage supplemented by eye observations. The lower curve (C) shows the duration of light sprinkling rains, or light flurries of snow, with amounts too small for accurate measurements.

are mostly of the kind accompanying thunderstorms. The former have a duration averaging more than double those of the latter.

An examination of the figures in the table above will show that the average duration of rainfall or snowfall is a little less than eight hours, when only such storms are considered as yield an appreciable amount of precipitation. When "traces" are included, the average duration is somewhat above eight hours. The summer rains are less than half the duration of those of the winter, spring and fall; they are obviously of the thundershower type, while the rains of the winter, spring and fall occur mostly in connection with the cyclonic depressions. The entire interval between the beginning and ending of precipitation of each storm was considered as the duration of rainfall or snowfall, regardless of interruptions in the continuity of the fall.

The duration of the actual period of precipitation is something quite different from the duration of the general storm, or local atmospheric disturbance in connection with which the precipitation occurs. During the passage of a storm over any given locality, there are likely to be many beginnings and endings of precipitation with intervals of a few minutes or a few hours with no precipitation, or of so small an amount as to be negligible. There is a certain type of storm which is of comparatively frequent occurrence in the Middle Atlantic states—the "northeaster;" this storm is generally accompanied by heavy and persistent rainfall. But even in this class the intensity of rainfall varies greatly from hour to hour and it is generally made up of several showers with intervals of several hours without appreciable rainfall. A list of storms accompanied by an uninterrupted rainfall exceeding 24 hours in the city of Baltimore during the past ten years would not be a very long one, the number probably not exceeding three or four per year.

The following list comprises rains of exceptionally long duration, which have occurred during the ten-year period ending with 1903. In these storms the rainfall was practically continuous, although in most of them there were intervals of a few hours during which only light sprinkling, or misting, rains were recorded.

RAIN AND SNOW STORMS OF LONG DURATION.

			Am't.
1893,	Apr. 19-21	44 hours of actual precipitation.	1.14 In.
1894,	Apr. 10-12	52 " " "	1.95 "
	Dec. 10-12	49 " " "	2.01 "
1895,	Jan. 8-10	55 " " "	1.55 "
	Apr. 27-May 1	102 " " "	3.69 "
	Nov. 24-25	42 " " "	0.13 "
1897,	Dec. 3-5	44 " " "	1.18 "
1898,	Feb. 18-21	47 " " "	1.18 "
	Dec. 3-4	44 " " "	1.27 "
1899,	Feb. 11-13	54 " " "	1.56 "
1900,	Feb. 16-17	41 " " "	0.40 "
1902,	Feb. 20-22	51 " " "	2.53 "
	Nov. 24-26	44 " " "	1.60 "
1903,	Apr. 13-15	43 " " "	1.68 "

The long-continued rains generally occur in connection with our "northeasters," depressions originating over the Gulf of Mexico, or in the West Indies, and moving northeastward directly over Maryland, or following the Atlantic coast line. The most notable case in the list of long-continued rain storms is that of the spring of 1895, when rain, though sometimes very light, fell for practically 102 consecutive hours, beginning at 8 a. m., April 27, and ending at 2 p. m., May 1. The total precipitation for the entire period (3.69 inches) was not very large, though the rate of fall was at times excessive. There was no well-defined storm area near Baltimore at any time during the period. The barometer was high over the New England states, while there was a shallow and ill-defined depression over the Gulf of Mexico which moved slowly northward and eastward some distance off the south and middle Atlantic coast, causing a steady northeast wind at Baltimore.

Frequency of Precipitation of Stated Amounts.

A table of monthly and annual precipitation as usually compiled may lead to erroneous inferences as to its agricultural value. The beneficial effects of rainfall depend not only on the quantity, but often to an equal extent upon the time of occurrence and the rate of precipitation. A given amount falling rapidly is of less value, agriculturally, than an equal or even less amount falling more slowly, as a rule. The greater portion of an excessive rain is apt to find its way to the streams immediately, while the lighter rains will soak into the ground to be utilized later in

the processes of plant life. It is of great importance to know the exact seasonal distribution of rainfall in order to determine to what extent it

TABLE XL.—NUMBER OF DAYS WITH PRECIPITATION OF ONE HUNDREDTH OF AN INCH OR MORE.

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
1871	5	7	10	6	6	8	16	12	4	10	10	10	104
1872	8	8	14	10	9	9	10	18	9	8	8	11	122
1873	13	12	9	14	14	8	11	21	14	11	9	11	147
1874	12	8	8	15	10	8	9	10	9	2	6	12	109
1875	11	8	12	11	8	11	14	17	8	9	11	16	136
1876	11	14	13	7	10	11	15	13	15	14	12	9	144
1877	14	6	15	14	9	9	13	7	8	12	14	8	129
1878	13	9	11	11	13	12	11	16	9	9	10	9	133
1879	9	13	15	9	8	8	7	11	10	5	8	16	119
1880	15	12	18	14	5	14	12	14	9	10	14	17	154
1881	14	10	14	13	10	14	8	7	8	9	10	15	132
1882	17	11	14	11	21	8	10	13	13	13	10	8	149
1883	19	13	8	15	9	16	14	7	9	13	10	12	145
1884	15	19	19	11	13	10	13	10	2	9	8	13	142
1885	11	15	12	9	12	8	10	15	8	11	13	6	130
1886	16	8	12	7	17	13	12	8	8	7	10	16	134
1887	10	16	13	13	9	12	12	7	10	9	8	10	129
1888	11	12	14	9	17	7	8	12	16	15	10	7	138
1889	12	11	13	16	16	14	18	9	17	12	16	10	164
1890	13	13	16	13	18	6	10	15	12	16	9	14	155
1891	13	16	18	10	14	11	14	13	5	9	11	9	143
1892	12	14	13	12	15	13	9	10	9	3	11	8	129
1893	8	14	11	15	14	14	11	6	8	9	11	11	132
1894	12	15	8	12	18	11	9	8	10	11	9	11	134
1895	16	5	13	11	13	10	9	6	5	4	10	12	114
1896	4	12	14	8	9	13	15	8	10	6	11	5	115
1897	13	13	12	10	13	12	14	8	4	12	15	15	141
1898	12	6	19	12	12	6	8	11	4	12	14	9	125
1899	14	17	12	4	13	7	10	13	10	6	5	7	118
1900	11	13	12	10	7	11	9	10	7	10	8	7	115
1901	6	4	12	14	14	7	11	11	12	5	4	12	112
1902	10	8	11	9	8	11	15	7	12	7	9	15	122
1903	12	10	13	9	7	14	13	14	5	8	7	9	121
Averages, 1871-1880.	11.1	9.7	12.5	11.1	9.2	9.8	11.8	13.9	9.5	9.0	10.2	11.9	129.7
" 1881-1890.	13.8	12.8	14.5	11.7	14.2	10.8	11.5	10.3	10.3	11.4	10.4	11.1	141.8
" 1891-1900.	11.5	12.5	13.2	10.4	12.8	10.8	10.8	9.3	7.2	8.2	10.5	9.4	126.6
" 1871-1903.	11.9	11.3	13.3	11.0	11.8	10.5	11.5	11.1	9.1	9.3	10.0	10.9	131.4

Table XL shows the frequency of occurrence of an appreciable amount of rain or snow (.01 inch) for each month of every year from 1871 to 1903, also the total annual frequency, and the average frequency for each ten year period and for the entire period of 33 years.

may be counted upon at the critical stages of plant growth. A statement of monthly amounts will not reveal these important facts with sufficient accuracy.

Tables have been prepared to show the total monthly and annual frequency of appreciable amounts of rainfall in each year from 1871 to

TABLE XLI.—ANNUAL NUMBER OF DAYS WITH PRECIPITATION OF STATED AMOUNTS.

Year.	Less than .01 inch.	.01 to .10 inch.	.11 to .25 inch.	.26 to .50 inch.	.51 to 1.00 inch.	Over 1.00 inch.	.01 inch or more.
1871	..	37	23	25	11	8	104
1872	..	56	27	16	18	5	122
1873	..	62	31	22	23	9	147
1874	..	50	20	20	12	7	109
1875	..	57	28	20	21	10	136
1876	..	62	35	22	14	11	144
1877	..	61	18	22	18	10	129
1878	..	63	16	19	22	13	133
1879	..	53	24	20	12	10	119
1880	..	73	38	22	11	10	154
1881	..	50	26	28	15	13	132
1882	24	69	30	22	18	10	149
1883	10	64	28	28	16	9	145
1884	12	61	20	32	20	9	142
1885	31	58	26	18	16	12	130
1886	24	57	25	22	14	16	134
1887	31	54	20	26	16	13	129
1888	37	62	32	17	14	13	138
1889	25	74	21	31	21	17	164
1890	30	67	35	22	21	10	155
1891	42	56	32	18	24	13	143
1892	43	50	16	29	25	9	129
1893	56	67	23	17	17	8	132
1894	43	63	21	26	13	11	134
1895	44	44	23	23	14	10	114
1896	56	53	21	12	20	9	115
1897	45	59	27	20	24	11	141
1898	54	45	34	22	17	7	125
1899	41	38	24	26	22	8	118
1900	46	50	25	21	14	5	115
1901	60	42	22	21	16	11	112
1902	50	46	22	19	19	16	122
1903	55	50	15	22	21	13	121
Average	39.0	56.2	25.1	22.1	17.5	10.5	131.4
Greatest	60	74	38	32	25	17	164
Least	10	37	15	12	11	5	104

Table XLI shows the number of days for each year from 1871 to 1903 upon which rain or melted snow was recorded to the depth indicated by the figures at the top of each column. Amounts less than .01 inch were not recorded until 1882.

1903 (Table XL), and of the total annual frequency of falls of stated amounts (Table XLI). These tables, together with those referred to later showing the rainfall frequency and amounts for each day of the

year and for each successive pentad and decade, give most of the facts necessary for a detailed study of the influence of rainfall upon plant growth in the vicinity of Baltimore. Some of the more conspicuous deductions from these tables are here summarized. Considering only days with an appreciable amount (0.01 inch or more), there are on the average 131 per year. The limits of variability are 164 and 104, occurring in 1889 and 1871 respectively. Such days are the least frequent in September and October, and most frequent in March. With an average

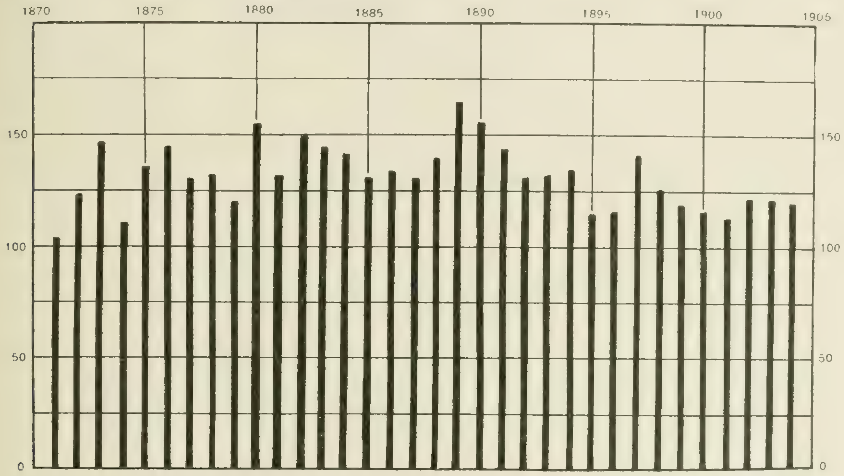


FIG. 49.—Variations in the Annual Frequency of Days with Appreciable Precipitation.

maximum frequency of 13.3 in March, there is a steady decrease to 9.1 in October, followed by an almost uniform increase to March. With normal conditions, the rainfall is ample at all periods of the year. Disastrous droughts are of rare occurrence. The most pronounced dry periods of the past 33 years will be referred to in subsequent pages. The variations in the total annual frequency of rainy days from year to year are confined within quite narrow limits (see Fig. 49). The successive ten-year averages from 1871 to 1900 are 130, 142, 127, respectively. Since 1895 the annual frequency has been continuously below the normal,

with the single exception of 1897; from 1880 to 1891 it was almost continuously above.

In addition to the days with an appreciable quantity of rainfall referred to in the above paragraphs, there are nearly forty per year, on the average, during which light sprinkling rains or mists are recorded. Their distribution throughout the year follows closely that of the days with appreciable rain. While the individual effect of these light rains is small, their aggregate annual value to vegetation cannot be neglected.

The most frequent quantity of rain or snow, and hence the most probable quantity to be expected in all months of the year, is some amount from 0.01 inch to 0.10 inch. The average daily rainfall for the year is 0.32 inch, neglecting traces. Hence, as already pointed out in the discussion of the temperature observations, the average value is not the most probable. The average monthly and annual frequency of stated amounts, based upon a record of 33 years, is shown in the following table:

FREQUENCY OF PRECIPITATION OF STATED AMOUNTS.

(Average for 33 years.)

Precipitation in hundredths of an inch.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Trace*	3.4	2.5	3.6	2.9	4.6	3.0	4.0	3.6	2.2	2.8	2.9	2.8	38.3
0.01 to 0.10	5.4	4.8	5.0	4.7	4.8	4.1	5.0	4.7	3.8	4.7	4.1	5.3	56.3
0.11 to .25	2.4	2.0	3.5	2.7	2.5	1.7	2.2	1.9	1.4	1.3	2.1	1.8	25.4
0.26 to 0.50	2.1	2.1	1.9	1.8	2.2	2.0	1.5	1.8	1.5	1.5	1.8	1.9	22.1
0.51 to 1.00	1.5	1.6	1.7	1.3	1.6	1.7	1.4	1.5	1.4	1.2	1.5	1.0	17.4
Over 1.00	0.5	0.8	0.9	0.6	0.8	0.8	1.4	1.2	1.2	0.7	0.7	0.9	10.4
.01 and over	11.9	11.3	13.3	11.0	11.8	10.5	11.5	11.1	9.1	9.3	10.0	10.9	131.4

*Average for 20 years.

Average Daily Rainfall.

In the following consideration of the question of the daily amount of rain or snow which falls throughout the year no account was taken of days upon which less than 0.01 inch was recorded. The period covered in determining the average daily rainfall was that from 1871 to 1900, or thirty years. The total amount of precipitation for each day was then divided by the number of days upon which precipitation occurred to the

amount of .01 inch or more, and this value regarded as the average daily rainfall and recorded in Table XLII.

TABLE XLII.—AVERAGE AMOUNT OF PRECIPITATION ON DAYS WITH RAIN OR SNOW.

(In hundredths of an inch.)

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
1	.24	.08	.29	.17	.24	.35	.36	.35	.16	.15	.53	.29	
2	.16	.35	.25	.22	.18	.20	.71	.33	.28	.28	.23	.15	
3	.15	.34	.35	.51	.28	.30	.39	.60	.48	.14	.31	.39	
4	.32	.23	.46	.23	.31	.40	.29	.11	.17	.55	.39	.30	
5	.25	.25	.23	.25	.23	.41	.36	.38	.57	.26	.48	.42	
6	.35	.48	.14	.33	.25	.24	.17	.55	.84	.37	.21	.34	
7	.30	.19	.24	.22	.49	.33	.22	.78	.36	.15	.26	.70	
8	.34	.27	.31	.36	.61	.33	.52	.46	.57	35	.42	.11	
9	.33	.51	.48	.47	.22	.49	.28	.11	.32	.10	.29	.11	
10	.29	.28	.33	.34	.15	.21	.40	.56	.24	.57	.24	.60	
11	.32	.54	.46	.23	.17	.44	.62	.30	.60	.06	.14	.18	
12	.21	.38	.37	.17	.44	.25	.32	.47	.39	.33	.19	.25	
13	.39	.42	.14	.25	.22	.25	.33	.50	.26	.38	.30	.29	
14	.24	.20	.19	.21	.34	.47	.29	.12	.45	.17	.35	.39	
15	.39	.22	.25	.18	.43	.44	.54	.18	.58	.21	.37	.33	
16	.14	.61	.39	.13	.37	.36	.24	.43	.80	.17	.07	.16	
17	.27	.21	.13	.30	.18	.30	.40	.50	.74	.08	.21	.46	
18	.13	.28	.35	.28	.25	.72	.39	.31	.13	.04	.35	.22	
19	.35	.27	.45	.19	.39	.22	.33	.11	.93	.49	.39	.22	
20	.21	.27	.37	.25	.41	.57	.47	.26	.23	.50	.17	.41	
21	.38	.31	.21	.35	.41	.29	.69	.53	.16	.30	.20	.32	
22	.25	.41	.35	.29	.33	.49	.49	.25	.30	.22	.16	.29	
23	.13	.44	.16	.14	.33	.44	.19	.37	.57	.86	.50	.11	
24	.43	.34	.15	.19	.32	.29	.36	.33	.34	.27	.54	.32	
25	.30	.36	.27	.50	.24	.32	.41	.56	.47	.46	.23	.14	
26	.24	.26	.34	.48	.37	.40	.54	.15	.28	.27	.37	.20	
27	.27	.17	.51	.45	.26	.54	.36	1.03	.35	.32	.35	.28	
28	.11	.24	.31	.43	.21	.70	.38	.14	.20	.09	.28	.16	
29	.18	.45	.33	.36	.21	.17	.39	.54	.28	.18	.29	.37	
30	.20	..	.40	.24	.21	.18	.65	.20	.12	.44	.11	.37	
31	.26	..	.32	..	.22	..	.54	.28	..	.39	..	.19	
Average	0.26	0.32	0.31	0.29	0.30	0.37	0.41	0.38	0.41	0.30	0.30	0.29	0.32

Table XLII. In determining the average daily amount of precipitation in the above table, the total precipitation of the month was divided by the number of days upon which rain fell to the depth of one hundredth of an inch, or snow to the depth of one tenth of an inch. The record is based upon daily observations during the period of 30 years from 1871 to 1900.

The results are interesting, among other reasons, as showing the great variability in the amounts for adjacent days, even in values representing an average for thirty years. The average amount for any particular day is at any time likely to be materially altered by the occurrence of a single

heavy rain. The heaviest rains occur in the warm months of June, July, August and September, while the smaller amounts are confined, in the main, to the colder months. The influence of a single heavy rainfall on the average amount for thirty-one years is clearly shown in the exceptionally high average fall for the 27th of August. The average for all

TABLE XLIII.—AVERAGE AMOUNT OF PRECIPITATION BY PENTADS AND DECADES.

PENTADS.

(Pentads ending on stated dates.)

January.		February.		March.		April.		May.		June.	
5th	.22	4th	.25	1st	.26	5th	.28	5th	.25	4th	.29
10	.32	9	.34	6	.29	10	.34	10	.34	9	.36
15	.31	14	.36	11	.36	15	.21	15	.32	14	.32
20	.22	19	.32	16	.27	20	.23	20	.32	19	.41
25	.30	24	.35	21	.30	25	.29	25	.33	24	.42
30	.20	....	....	26	.25	30	.39	30	.25	29	.43
....	....	...	....	31	.37	....	...	....	....	....	....

July.		August.		September.		October.		November.		December.	
4th	.39	3rd	.49	2nd	.29	2nd	.21	1st	.33	1st	.26
9	.31	8	.46	7	.48	7	.29	6	.32	6	.32
14	.39	13	.39	12	.42	12	.28	11	.27	11	.34
19	.38	18	.31	17	.57	17	.20	16	.26	16	.28
24	.44	23	.30	22	.35	22	.31	21	.26	21	.33
29	.42	28	.44	27	.40	27	.44	26	.36	26	.21
....	....	....	....	...	....	....	....	....	....	31	.27

DECADES.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1st Decade....	.27	.30	.31	.31	.30	.33	.37	.42	.40	.29	.34	.34
2nd "	.26	.34	.31	.22	.32	.40	.39	.32	.51	.24	.25	.29
3rd "	.25	.33	.30	.34	.28	.38	.45	.40	.31	.35	.30	.25

Table XLIII. The average amount of precipitation recorded during each successive five-day period and ten-day period throughout the year is shown in the above tables. The figures are based upon a 30-year record, and represent approximately the most probable amount of precipitation to be expected within the same pentads and decades in coming years.

August days is 0.38 inch, while for the 27th it is 1.03 inch. On the 27th of August, 1882, the amount recorded was two inches. The total number of times rain occurred on the 27th of August from 1871 to 1901 was but 5, while the average frequency for all the days of the month was 11.4. The variable character of the rainfall from day to day is more readily seen when represented in graphical form as in Plate IX. Some of the

smallest daily amounts belong to the month of October. The average fall for the 17th of this month is but .08 inch, and that for the 18th but .04 inch. The general average for the entire year is 0.32 inch per day.

TABLE XLIV.—FREQUENCY OF PRECIPITATION ON EACH DAY OF THE YEAR FROM 1871 to 1901.

(Precipitation of .01 inch or more.)

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
1	15	11	10	11	9	12	10	16	4	6	8	9	
2	13	9	14	10	9	12	11	16	4	8	9	8	
3	4	16	12	9	10	12	6	8	6	8	12	7	
4	10	15	13	11	13	13	11	13	7	7	7	14	
5	16	14	14	9	14	11	16	11	5	8	6	11	
6	15	13	10	10	18	11	13	10	13	10	9	9	
7	10	17	11	11	13	9	10	9	11	12	11	7	
8	8	15	13	12	11	11	11	11	8	10	12	12	
9	15	9	15	14	11	9	6	9	9	5	16	9	
10	12	12	13	15	11	13	7	10	12	4	13	8	
11	12	13	13	10	13	11	12	11	13	7	11	10	
12	15	14	16	14	9	14	10	14	13	13	11	11	
13	13	16	15	10	11	12	13	14	13	12	8	9	
14	12	14	13	8	12	7	11	12	9	12	8	12	
15	11	9	13	14	14	7	11	15	13	5	9	13	
16	15	10	13	15	14	14	9	11	11	5	6	5	
17	15	13	12	11	7	17	8	9	12	6	13	12	
18	13	14	8	12	14	9	10	13	9	6	12	10	
19	12	13	16	11	13	9	11	9	8	6	10	9	
20	13	12	16	13	11	6	12	8	9	9	11	9	
21	12	13	15	7	16	11	8	11	8	12	9	12	
22	9	11	12	9	13	11	10	15	10	12	12	14	
23	9	6	13	12	14	7	12	15	11	13	17	13	
24	13	8	12	12	14	6	11	14	7	11	13	11	
25	14	19	12	12	14	16	13	12	9	7	8	11	
26	9	14	14	13	13	11	17	9	12	12	14	20	
27	10	11	12	13	13	10	19	5	6	13	7	13	
28	15	10	15	18	10	11	18	6	7	16	13	11	
29	13	..	14	15	9	13	14	10	9	16	12	12	
30	8	..	8	5	11	8	10	13	14	11	8	10	
31	14	..	13	..	13	..	13	13	..	12	..	17	
Average	12.1	12.5	12.9	11.5	12.2	10.8	11.4	11.4	9.4	9.5	10.5	10.9	11.3
Greatest	16	19	16	15	18	17	19	16	14	16	17	20	20
Least	4	6	8	5	7	6	6	5	4	4	6	5	4

Table XLIV. This table indicates the number of times in thirty-one years that rain or melted snow was recorded to the depth of one hundredth of an inch or more upon each day of the year. Thus we learn that rain or snow fell but 4 times in 31 years on the 3rd of January, that precipitation was recorded 20 times on the 26th of December during the same period, etc. The days of most frequent and least frequent precipitation are also shown for each month.

July and September have the highest average, with 0.41 inch, and January, with 0.26 inch, the lowest.

As the daily averages are so variable in character, they have been grouped in periods of five and ten days, and average values determined for each pentad and decade of the year (see Table XLIII). By this process of smoothing out accidental irregularities, we obtain values which represent more nearly the most probable precipitation to be expected upon any day of each pentad or decade (see also Plate IX).

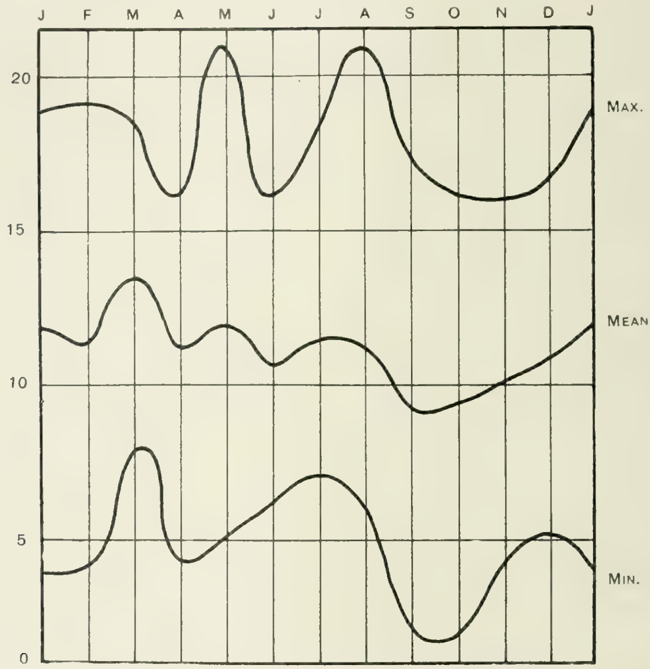


FIG. 50.—Monthly Frequency of Precipitation.

The maximum monthly frequency, the mean frequency and the least monthly frequency of occurrence of days with an appreciable amount of precipitation are shown, respectively, by the upper, the middle and the lower curves.

DAILY RAINFALL FREQUENCY.

A matter of considerable importance to agricultural and commercial interests is the frequency of the occurrence of rain or snow in appreciable quantities. This has been determined with great accuracy for the vicinity of Baltimore, especially since 1871, when systematic observations were begun by the Weather Bureau. Here again as in the determination

of the average daily quantity of precipitation, the average values for adjacent days vary remarkably. Thus the average frequency for January 2 is 13, while that of January 3 is but 4. For June 24 and 25, the values are 6 and 16 respectively. The day upon which rain or snow fell the greatest number of times from 1871 to 1901 is December 26, namely, 20 times in 31 years. The lower limit, namely, 4 times, belongs to January 3, September 1 and 2 and October 10. (See Table XLIV and Plate IX.)

The table throws an interesting side-light on the mooted question of the occurrence of "equinoctial storms." Are rains any more frequent on March 21 and September 21 than on the days immediately preceding and following? On March 21 rain fell 15 times in 31 years; on March 19 and 20, 16 times; on 22 and 23, 12 and 13 times respectively. The average for all days in March is 13 times. On September 21 rain fell 8 times in 31 years; the average for all days of the month is 9.4 times. That is, an appreciable amount of rain fell on only 26 per cent of the September equinoctial days of the 31 years, or 4 per cent below the average for all days of September. These figures show that rain is not as likely to occur on these days as on many other days of the month.

The Probability of Rain.

If we divide the actual number of occurrences of rain on any given day by the number expressing the total number of years under consideration (in this case 31), we obtain an expression which in a rough way represents the percentage of expectancy of rainfall, or the rainfall probability, for that day. Rainfall in the middle latitudes is too erratic in its occurrence to place much reliance upon this percentage as a forecast for any particular day; if, however, we have a long series of observations and take the average value for 5 successive days, we arrive at a figure which more accurately represents the most probable percentage of occurrences of rainfall for any one of the five days. This has been done in Table XLV and the results graphically represented in Plate IX. The curve based on 5-day means shows some periods of the year to be decidedly freer from rain than others, although there is a fairly uniform

distribution of precipitation throughout the year. The period from the middle of September to the middle of October, for example, has shown in 31 years from 1871 to 1901, an average rainfall frequency of about 28 per cent. The month of March, on the other hand, shows a record of about 42 per cent. The last week of July shows a probability of 52 per cent, the highest for any week in the year. The average daily proba-

TABLE XLV.—RAINFALL PROBABILITY BY PENTADS AND DECADES.

(In percentage of possible frequency.)

PENTADS.

(Pentads ending on stated dates.)

January.		February.		March.		April.		May.		June.	
5th	37.4	4th	41.8	1st	43.7	5th	32.0	5th	35.4	4th	40.2
10	38.6	9	43.8	6	40.6	10	39.8	10	41.0	9	32.6
15	40.6	14	44.6	11	41.8	15	36.0	15	38.0	14	36.6
20	43.8	19	38.0	16	45.2	20	39.8	20	37.8	19	36.0
25	36.8	24	32.2	21	43.4	25	33.6	25	45.8	24	26.0
30	35.4	....	....	26	40.8	30	45.8	30	36.0	29	39.2
....	....	....	....	31	40.0	....	....	....	....	....	....

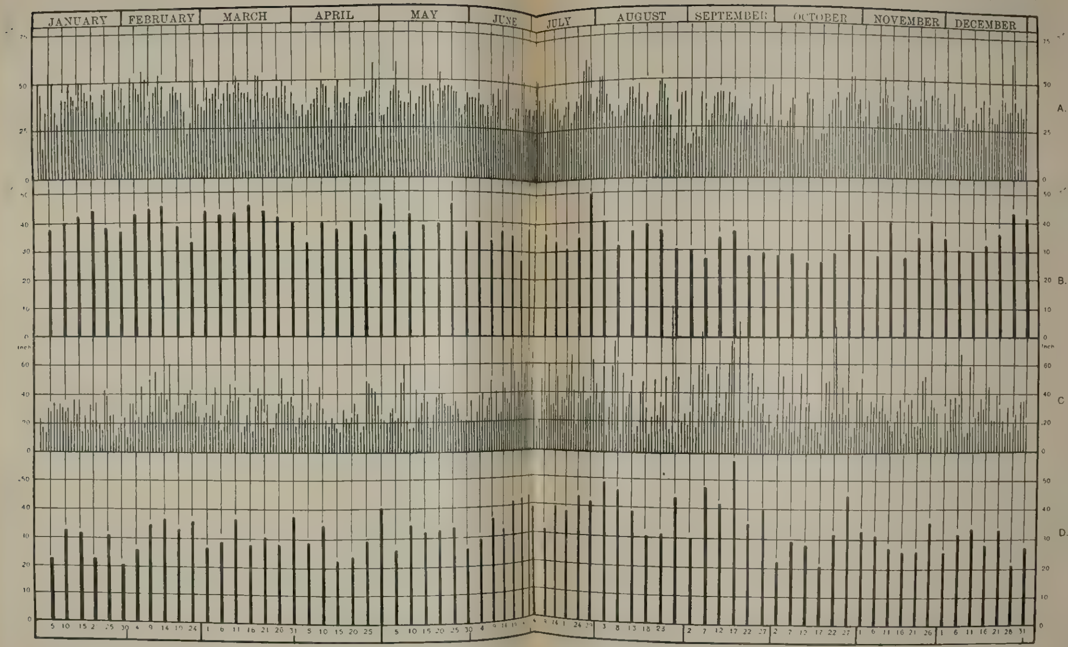
July.		August.		September.		October.		November.		December.	
4th	29.4	3rd	40.8	2nd	29.6	2nd	28.2	1st	40.8	1st	31.6
9	36.0	8	30.6	7	26.8	7	29.0	6	27.6	6	31.4
14	34.0	13	37.2	12	35.6	12	25.6	11	40.6	11	29.6
19	31.4	18	38.6	17	37.4	17	25.8	16	27.0	16	32.2
24	34.2	23	37.2	22	28.4	22	29.0	21	35.4	21	33.6
29	52.2	28	29.8	27	28.8	27	36.0	26	44.4	26	44.2
....	....	....	....	..	....	....	....	....	....	31	40.6

DECADES.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1st Decade	38.0	42.2	40.2	35.9	38.2	36.4	32.3	36.4	26.0	25.1	33.2	30.2
2nd "	42.2	41.3	43.7	37.9	37.9	34.0	34.4	37.3	35.5	26.0	31.8	28.2
3rd "	36.9	39.1	41.1	37.4	41.0	33.3	42.5	35.9	29.8	39.6	36.5	42.1

Table XLV. The figures in this table represent approximately the probability of rain or snow upon any one of each of the stated five- and ten-day periods throughout the year, expressed in terms of percentage of the total number of similar days in thirty-one years, or of the possible frequency. For example, the probability of the occurrence of rain upon the 15th of March (or any stated day from the 11th to the 20th) is expressed by 43.7%; for the 15th of October, by 26.0%. If rain had occurred upon every 15th of March and 15th of October in the thirty-one years from 1871 to 1901 the percentages of probability of rain upon these days would have been represented by 100.

bility for the entire year is 36 per cent; the highest for any one day is 64 per cent, namely, for December 26, and the lowest is 13 per cent, for January 3, September 1 and October 10. The probability of rain is less



PRECIPITATION PROBABILITY.

A Precipitation frequency for each day of the year
B Precipitation frequency for each successive 5 day period of the year } Expressed as percentages of the possible frequency in 30 years
C Average amount of precipitation for each day of the year
D Average amount of precipitation for each successive 5 day period of the year } Including only days with rain or snow

than 20 per cent on but few days of the year, and does not often exceed 50 per cent.

The probability of precipitation at Baltimore on the following days may be of special interest:

Jan. 1,	48 per cent.	May 30,	35 per cent.
Feb. 22,	35 " "	July 4,	35 " "
Mch. 4,	42 " "	Sept. 1,	13 " "
Mch. 21,	48 " "	Sept. 12,	42 " "
Apr. 30,	16 " "	Dec. 25,	35 " "
May 1,	29 " "	Thanksgiving Day	35 per cent.

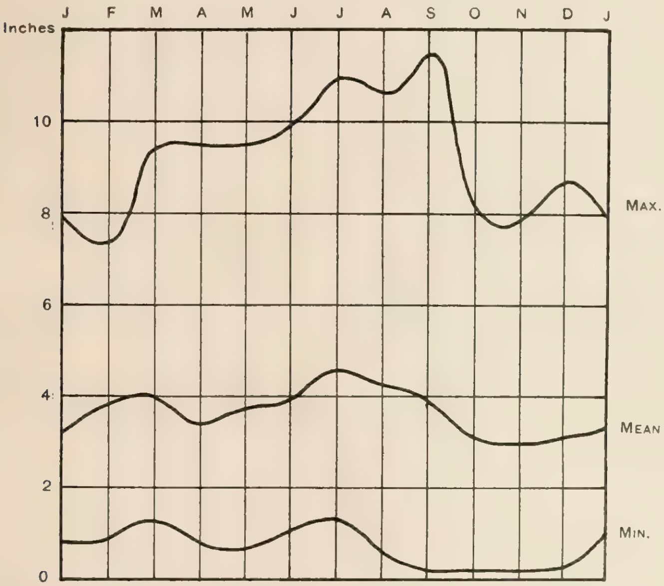


FIG. 51.—The Monthly Amount of Precipitation.

The upper line indicates the variations in the maximum monthly rainfall from month to month; the middle line shows the mean monthly rainfall based on 30 years of observations; the lower line shows the least monthly precipitation recorded during each month in 30 years.

THE MONTHLY PRECIPITATION.

The usual method of representing the precipitation of any given locality is by means of monthly and annual amounts. Owing to the great variability in the character of rainfall and snowfall, a great many years of continuous observations made under practically unchanged exposure of the gauge are required. The vicinity of Baltimore has to its

TABLE XLVI.—TOTAL MONTHLY AND ANNUAL PRECIPITATION FOR 87 YEARS.

Year.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1817	2.25	2.80	4.50	1.50	2.60	9.00	3.50	10.00	3.30	1.80	3.70	3.60	48.55
1818	0.90	2.00	3.00	2.10	6.45	1.15	4.10	2.00	3.20	3.10	2.00	2.60	32.60
1819	0.70	1.90	4.55	2.70	4.10	1.30	2.20	4.30	3.00	0.70	1.10	2.20	28.75
1820	2.80	2.20	3.30	1.10	4.40	4.60	2.20	8.00	1.50	7.80	2.70	1.90	42.50
1821	3.30	5.40	1.70	2.10	5.10	1.80	7.50	0.30	10.70	3.40	5.60	3.30	50.20
1822	1.80	4.80	1.30	2.10	1.50	1.50	4.35	0.80	2.25	2.50	5.10	1.20	29.20
1823	5.60	0.70	7.10	1.80	2.10	1.60	3.60	4.10	5.80	2.80	3.10	6.25	44.55
1824	2.30	5.90	4.30	4.70	2.95	5.03	3.37	4.50	2.94	1.77	2.27	2.25	42.28
1825	*0.62*	*2.87*	*4.53*	*0.67*	*1.59*	*3.08*	*1.74*	*3.21*	*2.47*	*0.88*	*1.23*	*3.36*	26.25
1826	*0.81*	*1.85*	*5.70*	*3.41*	*0.21*	*3.86*	*3.20*	*2.40*	*1.92*	*4.54*	*1.62*	*1.16*	30.68
1827	*2.03*	*3.13*	*1.13*	*2.47*	*2.29*	*1.80*	*2.56*	*4.95*	*0.83*	*4.60*	*3.95*	*2.95*	32.69
1828	*1.46*	*2.41*	*3.25*	*3.37*	*3.18*	*2.28*	*4.68*	*1.35*	*4.28*	*0.99*	*5.51*	*0.25*	33.01
1829	5.50	4.40	9.10	4.40	3.40	8.50	4.64	*3.98*	*1.93*	*1.72*	*3.32*	*1.37*	52.26
1830	*1.17*	*1.79*	*4.02*	*1.57*	*3.42*	*4.92*	*3.55*	*3.35*	*2.76*	*3.32*	*4.42*	*4.68*	38.97
1831	*4.38*	*2.13*	*2.87*	*4.61*	*1.01*	*2.98*	*3.64*	*4.64*	*4.92*	*3.48*	*1.65*	*1.09*	37.40
1832	*3.24*	*2.33*	*1.80*	*2.61*	*4.90*	*1.37*	*2.24*	*4.90*	*1.38*	*2.60*	*2.21*	*4.69*	34.27
1833	*2.81*	*1.05*	*2.12*	*0.56*	*5.33*	*4.36*	*3.62*	*2.94*	*3.56*	*7.92*	*1.89*	*5.12*	41.28
1834	*1.77*	*1.93*	*1.92*	*2.47*	*3.21*	*3.32*	*3.80*	*0.59*	*3.33*	*2.51*	*2.55*	*2.11*	29.51
1835	*1.96*	*1.57*	*3.73*	*3.82*	*1.83*	*5.15*	*5.78*	*1.81*	*2.49*	*0.85*	*2.69*	*2.42*	34.10
1836	3.94	3.41	1.64	4.23	4.10	9.20	2.35	6.70	3.15	4.00	4.80	7.10	54.62
1837	2.10	3.10	6.30	2.10	4.20	4.90	4.30	5.10	3.80	3.10	3.40	2.60	45.00
1838	2.10	2.90	4.50	2.80	4.30	4.70	1.90	9.10	4.50	3.10	2.70	4.50	47.10
1839	3.50	3.60	4.00	9.10	4.50	4.10	5.60	2.20	1.90	1.60	2.80	8.80	51.70
1840	2.30	2.30	2.70	4.30	3.90	5.10	1.85	2.35	2.80	4.50	2.15	3.25	37.50
1841	6.10	1.40	5.95	4.50	2.75	4.35	1.35	4.00	2.30	2.80	3.30	5.10	43.90
1842	1.80	3.35	2.40	4.30	4.00	2.65	3.70	4.40	1.00	1.40	2.75	3.35	35.10
1843	1.60	2.20	3.80	2.90	3.55	0.90	5.40	7.82	10.50	1.97	4.25	3.90	48.79
1844	3.65	1.45	3.00	1.60	4.00	1.70	3.90	0.31	4.47	3.03	1.85	3.50	32.46
1845	2.40	3.59	1.70	1.49	2.36	2.93	1.26	2.77	1.51	3.73	1.22	3.43	28.39
1846	2.83	1.82	3.54	2.38	5.77	1.78	6.89	7.20	3.88	1.30	7.17	2.10	46.66
1847	2.92	3.42	2.38	0.41	1.19	3.36	2.51	2.97	5.55	3.38	2.54	2.38	33.01
1848	1.58	0.94	2.70	0.81	2.96	4.24	4.42	3.24	1.64	7.35	1.44	3.10	34.42
1849	1.02	1.15	3.63	0.87	4.18	1.50	2.06	2.55	1.90	6.27	1.06	4.44	30.63
1850	3.58	2.43	5.90	3.85	3.08	1.66	3.10	4.70	4.70	3.10	4.30	4.40	44.80
1851	1.70	2.90	5.70	4.70	4.60	1.20	4.20	3.30	0.50	2.20	5.60	1.50	38.10
1852	2.60	3.60	3.90	7.80	1.70	2.70	5.70	4.60	2.20	2.60	7.90	6.20	51.50
1853	1.30	3.40	2.70	3.10	4 30	0.60	3.30	4.70	2.40	4.40	3.50	2.30	36.00
1854	4.40	4.90	4.70	7.20	5.20	4.80	2.60	3.00	4.10	7.10	7.30	3.90	59.20
1855	2.50	4.00	2.80	0.39	0.91	2.79	2.62	2.50	2.30	3.70	1.20	3.60	29.31
1856	2.11	0.50	2.47	1.48	1.19	0.92	1.82	4.88	2.83	0.77	1.85	2.05	22.87
1857	3.50	0.66	2.30	1.84	3.23	7.45	2.47	4.43	1.40	2.89	1.87	6.33	38.37
1858	1.83	1.61	1.31	4.33	9.08	4.90	3.23	3.37	4.44	2.34	3.97	5.65	46.06
1859	7.06	5.74	6.26	6.96	2.74	1.16	6.20	3.76	*7.03*	*2.38*	*3.20*	*3.15*	55.64
1860	*2.29*	*2.42*	*1.32*	*3.35*	*3.48*	*2.44*	*0.77*	*7.25*	*2.69*	*3.49*	*5.05*	*2.99*	37.54
1861	*3.70*	*1.79*	*3.82*	5.13	4.76	2.38	7.06	3.31	1.80	2.96	5.48	1.36	43.55
1862	0.60	*4.11*	*3.45*	*3.67*	*2.12*	*5.71*	*2.11*	*0.85*	*3.70*	*3.69*	*3.97*	*1.50*	35.48
1863	*3.33*	*4.15*	*5.79*	*6.25*	*4.10*	*3.53*	*5.29*	*1.30*	*0.91*	*1.84*	*2.30*	*4.18*	42.97
1864	0.80	0.14	4.23	3.54	3.39	0.82	0.41	2.36	2.19	*1.33*	2.41	1.40	23.02
1865	1.19	1.21	2.62	2.82	4.92	*3.93*	1.74	1.90	1.81	2.68	2.50	5.90	33.22
1866	2.50	4.90	1.40	*2.56*	0.20	*2.50*	*2.15*	*1.92*	4.20	1.55	1.10	2.50	27.48
1867	0.90	3.80	3.90	*1.56*	*6.63*	2.00	*2.03*	3.52	1.00	2.60	*2.49*	*2.47*	32.90
1868	*2.56*	*2.21*	*3.26*	1.65	2.80	*3.63*	5.05	1.33	4.48	0.50	3.50	1.66	32.63
1869	2.42	2.85	3.64	0.50	1.38	1.76	0.30	0.50	3.15	5.08	1.86	3.90	27.34
1870	2.00	1.50	1.90	3.03	2.52	3.37	0.35	1.68	1.76	3.00	0.28	1.04	22.43

TABLE XLVI CONT.—TOTAL MONTHLY AND ANNUAL PRECIPITATION FOR 87 YEARS.

Year.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1871	1.55	1.38	3.03	1.90	2.03	2.82	6.15	3.41	2.22	3.11	3.24	1.90	32.74
1872	0.88	1.46	3.06	3.06	1.44	4.16	1.58	4.59	5.06	4.08	3.17	2.22	34.76
1873	4.27	4.74	3.02	2.77	6.31	0.94	2.90	9.49	3.70	6.21	4.05	0.97	49.37
1874	2.22	3.18	1.41	6.65	1.92	1.11	4.30	3.47	4.83	0.16	2.48	1.90	33.63
1875	2.51	2.91	4.72	4.27	1.49	2.85	4.78	8.67	3.62	1.44	4.86	3.14	45.26
1876	1.67	2.96	6.37	1.90	4.94	4.09	5.64	1.76	10.52	2.79	2.74	1.32	46.70
1877	3.80	1.87	3.60	3.30	2.23	3.53	4.60	0.64	5.27	5.22	6.85	2.23	43.14
1878	4.51	3.31	4.74	4.19	5.38	4.09	4.66	4.82	0.82	4.41	3.55	5.61	50.09
1879	2.59	1.55	1.65	3.69	2.74	3.92	3.16	6.71	2.72	0.75	1.30	5.23	36.01
1880	2.26	1.96	4.82	3.07	1.23	5.48	6.47	4.44	1.78	2.64	2.86	4.89	41.90
1881	4.84	5.68	7.59	2.00	2.30	7.81	1.40	2.15	2.98	4.06	2.41	5.90	49.12
1882	5.38	3.73	3.43	2.14	3.42	2.30	4.02	5.10	9.38	0.86	0.65	1.70	42.11
1883	3.16	4.69	3.68	3.20	1.22	8.08	3.10	2.72	3.49	2.83	1.37	2.98	40.52
1884	4.81	6.69	6.37	2.65	3.17	2.51	9.43	1.74	0.09	1.42	3.09	3.91	45.88
1885	3.07	4.40	1.60	1.37	4.50	6.31	2.67	7.78	1.30	6.51	4.04	2.49	46.04
1886	4.48	5.49	4.85	2.06	7.07	5.64	8.08	3.94	1.90	1.39	4.09	3.12	52.11
1887	2.57	4.69	3.49	2.44	2.57	4.44	8.32	4.15	2.80	1.06	2.02	5.04	43.59
1888	3.35	2.83	4.62	2.11	4.22	3.22	2.82	6.17	4.90	2.99	3.04	3.26	43.53
1889	4.22	2.53	5.71	8.70	6.82	6.17	11.03	1.40	4.59	4.12	6.45	0.61	62.35
1890	1.80	4.80	4.07	3.94	5.98	2.42	3.61	6.44	4.76	5.73	0.74	2.67	46.96
1891	4.89	5.52	7.94	2.48	3.11	5.45	7.79	4.24	5.46	2.76	1.33	3.24	54.21
1892	6.42	2.41	7.20	3.15	6.35	4.87	4.07	1.83	2.36	0.26	3.85	2.28	45.05
1893	1.78	4.43	1.38	3.52	3.78	2.26	1.88	1.81	1.80	3.44	3.78	2.29	32.15
1894	1.46	3.53	1.19	3.80	7.26	3.29	1.73	1.41	4.75	3.80	1.98	4.12	38.32
1895	4.67	0.83	2.94	7.42	3.04	2.83	3.40	2.43	6.01	2.20	1.86	2.84	40.47
1896	2.62	7.07	4.70	1.44	1.61	3.94	6.32	1.93	4.14	1.11	3.34	0.37	38.59
1897	2.05	5.13	2.40	3.19	6.88	2.57	6.93	4.71	2.17	3.67	4.39	3.40	47.49
1898	2.99	1.32	2.58	1.84	3.86	1.06	3.51	6.09	1.56	3.97	4.34	3.34	36.46
1899	3.50	5.47	4.93	1.89	3.29	2.16	1.64	4.86	7.09	2.09	2.27	1.40	40.59
1900	2.11	4.65	3.17	2.06	1.00	4.34	1.51	2.91	4.26	1.68	1.81	2.07	31.57
1901	2.45	0.65	3.58	5.53	3.67	0.90	6.18	6.73	2.50	1.52	2.26	7.07	43.04
1902	3.05	4.68	3.41	2.90	1.62	4.30	2.45	4.31	7.19	6.85	3.70	5.66	50.13
1903	3.81	5.43	4.40	3.29	3.33	5.01	7.65	5.88	1.00	3.54	0.73	2.19	46.26
Averages.													
1821-1830	2.46	3.33	4.21	2.66	2.57	3.44	3.92	2.89	3.59	2.65	3.61	2.68	38.01
1831-1840	2.81	2.43	3.16	3.66	3.73	4.52	3.51	4.03	3.18	3.37	2.68	4.17	41.25
1841-1850	2.75	2.18	3.50	2.31	3.38	2.51	3.46	4.00	3.74	3.43	2.99	3.57	37.82
1851-1860	2.93	2.97	3.35	4.11	3.64	2.90	3.29	4.18	2.99	3.19	4.14	3.77	41.46
1861-1870	2.00	2.67	3.40	3.07	3.28	2.96	2.65	1.87	2.50	2.52	2.59	2.59	32.10
1817-1870	2.52	2.68	3.55	3.06	3.40	3.32	3.34	3.59	3.17	3.06	3.14	3.30	38.13
1871-1880	2.63	2.53	3.64	3.48	2.97	3.30	4.42	4.80	4.05	3.08	3.51	2.94	41.36
1881-1890	3.77	4.55	4.54	3.06	4.13	4.89	5.45	4.16	3.62	3.10	2.79	3.17	47.22
1891-1900	3.25	4.04	3.84	3.08	4.02	3.28	3.88	3.22	3.96	2.50	2.90	2.54	40.49
1871-1903	3.20	3.70	3.99	3.27	3.63	3.78	4.66	4.20	3.85	2.99	2.99	3.07	43.34

Table XLVI is a record of the total monthly and annual precipitation at Baltimore from 1817 to the close of 1903, including rain and melted snow. From 1817 to 1824 the record is that of Capt. Lewis Brantz; from 1836 to 1870, that of the U. S. Army Medical Department at Fort McHenry; from 1871 to 1903 that of the U. S. Weather Bureau. All figures in italics are interpolated values based upon the record of the Pennsylvania Hospital, Philadelphia, after applying the proper corrections to reduce the record to the Fort McHenry series. No attempt has been made in this table to reduce the entire record to a single uniform series.

credit a particularly long series of observations made under careful supervision by trained observers. From 1836 to 1870 the record contained in Table XLVI is that of the U. S. Army Medical Department kept at Fort McHenry. This is followed by the record of the U. S. Weather Bureau from 1871 to 1903. The observations from 1817 to 1824 were made by Capt. Lewis Brantz, in what was, in his time, West Baltimore. To

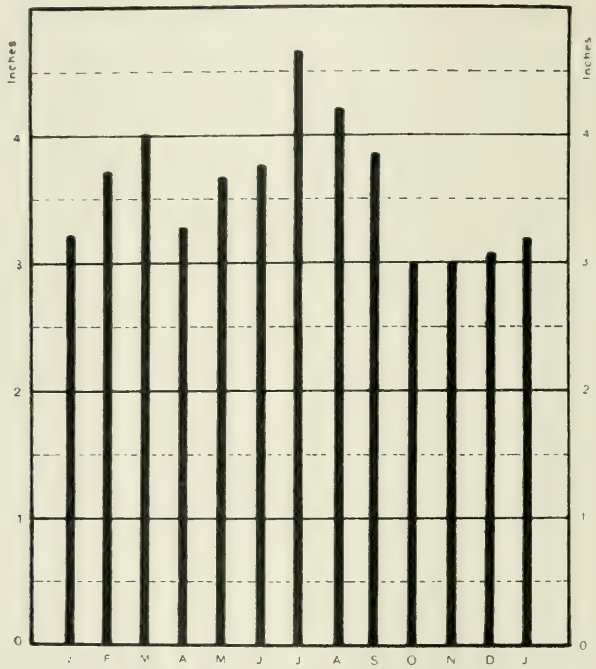


Fig. 52.—Mean Monthly Precipitation.

complete the record from 1817 to 1903, it was found necessary to interpolate the monthly and annual amounts for the years 1825 to 1835. This was done by computing the normal precipitation at the Pennsylvania Hospital of Philadelphia and applying the monthly and annual departures from this normal value to the normal amount for Fort McHenry. The records from 1817 to 1870 are fairly comparable. No attempt was made to reduce this series to that of the U. S. Weather Bureau from 1871 to 1903 in Table XLVI. The results of the two series may be compared

with entire safety by employing the departures from their respective normal values. This has been done in Fig. 54, in which the departures are graphically shown by months in regular chronological order for the entire period from 1817 to 1903. In Plate X the monthly, seasonal and annual departures are shown separately for the entire period. The Fort McHenry series may be reduced to the Weather Bureau series by adding the following differences to the monthly and annual normals of the former. These differences were computed from an overlapping record of twenty-one years from 1871 to 1891.

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
0.88	0.55	0.78	0.54	0.03	0.29	0.84	0.05	0.03	0.47	0.48	0.49	5.43

The record from 1871 to 1903 was made with great care and without any interruption. The average monthly and annual values computed from this series may be accepted with entire confidence as reliable averages for Baltimore. We have then the following figures to express the normal precipitation:

NORMAL MONTHLY PRECIPITATION.
(In inches and hundredths.)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
3.20	3.70	3.99	3.27	3.63	3.78	4.66	4.20	3.85	2.99	2.99	3.07	43.34

While the above figures represent the best average values available, they do not represent the most probable values to be expected during any future month or year. As precipitation is the most variable of all the climatic factors, a long series of accurate observations is necessary to establish a normal average, or an average which would not be materially altered by succeeding observations. The degree of variability at Baltimore is indicated by the figures in the following table of extremes during the period of 87 years from 1817 to 1903:

EXTREMES OF PRECIPITATION.
(1817-1903.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Above normal	4.54	3.37	5.55	6.04	5.68	5.88	6.37	6.41	7.53	4.86	4.76	5.50	21.07
Year	1859	1896	1829	1839	1858	1836	1889	1817	1821	1833	1852	1839	1854
Below normal	2.32	3.05	2.80	2.67	3.20	2.88	3.26	3.56	3.76	2.83	2.86	3.05	15.70
Year	1872	1901	1894	1855	1866	1901	1881	1877	1884	1874	1870	1828	1870
Range	6.86	6 42	8.35	8.71	8.88	8.76	9.63	9.97	11.29	7.69	7.62	8 55	36.77

The extreme monthly ranges are observed, from the above table, to be more than double the average monthly amounts, while the extreme annual range closely approaches the mean annual precipitation. Another interesting fact brought out by the above table is the ratio existing between excessive and deficient monthly precipitation. In every instance, excepting the month of February, the excessive amounts are in round numbers about double the deficiencies. As, in the long run, the sum of the excessive amounts must equal those of the deficient amounts in order to produce the normal value, it follows that a precipitation below the normal is the most frequent, and hence the most probable.

It is the excessive rainfall which disturbs average values to the greatest extent. A single heavy rainfall will occasionally materially change the average value for a long series of years. A case in point may be cited. In 1897 the average precipitation for the month of July for the southern part of Anne Arundel County, Maryland, based on a series of observations covering 7 years was 5.67 inches. On the 26th of July, 1897, during a local thunderstorm of great intensity, a rainfall of nearly 15 inches was recorded. This single fall changed the average July rainfall from 5.67 inches to 7.45 inches.

The Seasonal and Annual Precipitation.

The great variability in the total annual precipitation is best seen by an inspection of Fig. 53, in which the yearly amounts are presented graphically from 1817 to 1903 after reducing all observations to the Weather Bureau series. The dotted horizontal line represents the average height for the entire 87 years. The fluctuations from year to year are so irregular and vary so greatly in amount that it is difficult to detect any periodic movement. There are suggestions here and there in the diagram which point to possible periodic swings. There are groups of years during which the precipitation remained constantly above the normal value, and others with a persistent deficiency. Take, for instance, the period from 1850 to 1861 (see Fig. 53), when there was a decided annual excess with the exception of two or three years in the middle of the period; this was followed by 13 years of deficient pre-

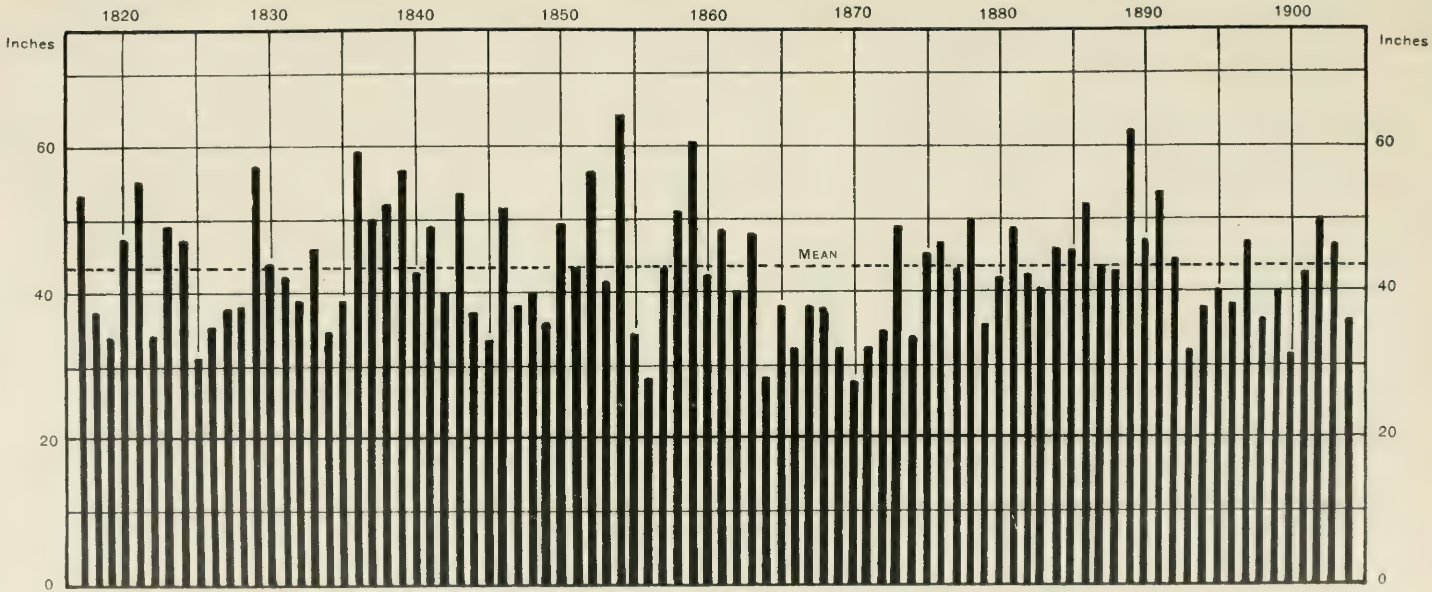


Fig. 53.—Variations in the Annual Amount of Precipitation for 1817 to 1904.

The eye observations from 1871 to 1904 are those of the U. S. Weather Bureau. A correction was applied to earlier observations in order to reduce them to the Weather Bureau series. The corrections were derived from an overlapping period of twenty-one years. The dotted horizontal line marks the average precipitation based on the Weather Bureau observations, namely, 43.34 inches.

cipitation; from 1873 to 1889 the annual values fluctuated a great deal, but on the whole there was a gradually increasing excess, culminating in 1889 in one of the heaviest annual falls recorded: in the following years there was diminishing rainfall with an average below the normal to the present time.

TABLE XLVII.—TOTAL SEASONAL PRECIPITATION FOR 87 YEARS.

Season	Winter	Spring	Summer	Autumn	Season	Winter	Spring	Summer	Autumn	Season	Winter	Spring	Summer	Autumn
....	....	....	....	....	1845–6	8.08	11.69	15.87	12.35	1875–6	7.77	13.21	11.49	16.05
1817	....	8.60	22.58	8.80	1846–7	8.44	3.98	8.84	11.47	1876–7	6.99	9.13	8.77	17.34
1817–8	6.50	11.55	7.25	8.30	1847–8	4.90	6.47	11.90	10.43	1877–8	10.05	14.31	13.57	8.78
1818–9	5.20	11.35	7.80	4.80	1848–9	5.27	8.68	6.11	9.23	1878–9	9.75	8.08	13.79	4.77
1819–20	7.20	8.80	14.80	12.00	1849–50	10.45	12.83	9.46	12.10	1879–80	9.45	9.12	16.39	7.28
1820–1	10.60	8.90	9.60	19.70	1850–1	9.00	15.00	8.70	8.30	1880–1	15.41	11.89	11.36	9.45
1821–2	9.90	4.90	6.65	9.85	1851–2	7.70	13.40	13.00	12.70	1881–2	15.01	8.99	11.42	10.89
1822–3	7.50	11.00	9.30	11.70	1852–3	10.90	10.10	8.60	10.30	1882–3	9.55	8.10	13.90	7.69
1823–4	14.45	11.95	12.90	6.98	1853.4	11.60	17.10	10.40	18.50	1883–4	14.48	12.19	13.68	4.60
1824–5	5.74	6.79	8.03	4.58	1854.5	10.40	4.10	7.91	7.20	1884–5	11.38	7.47	16.76	11.85
1825–6	6.02	9.32	9.46	8.08	1855–6	6.21	5.14	7.62	5.45	1885–6	12.46	13.98	17.66	7.38
1826–7	6.32	5.89	9.31	9.38	1856–7	6.21	7.37	14.35	6.16	1886–7	10.38	8.50	16.91	5.88
1827–8	6.82	9.80	8.31	10.78	1857–8	9.77	14.72	11.50	10.75	1887–8	11.22	10.95	12.21	10.93
1828–9	10.15	16.90	17.12	6.97	1858–9	18.45	15.96	11.12	12.61	1888–9	10.01	21.23	18.60	15.16
1829–30	4.33	9.01	11.82	10.50	1859–60	7.86	8.15	10.46	11.23	1889–90	7.21	13.99	12.47	11.23
1830–1	11.19	8.49	11.26	10.05	1860–1	8.48	13.71	12.75	10.24	1890–1	13.08	13.53	17.48	9.55
1831–2	6.66	9.31	8.51	6.19	1861–2	6.07	9.24	8.67	11.36	1891–2	12.07	16.70	10.77	6.47
1832–3	8.55	8.01	10.92	13.37	1862–3	8.98	16.14	10.12	5.05	1892–3	8.49	8.68	5.95	9.02
1833–4	8.82	7.60	7.71	8.39	1863–4	5.12	11.16	3.59	5.93	1893–4	7.28	12.25	6.43	10.53
1834–5	5.64	9.38	12.74	6.03	1864–5	3.80	10.36	7.57	6.99	1894–5	9.62	13.40	8.66	10.07
1835–6	9.77	9.97	18.25	11.95	1865–6	13.30	4.16	6.57	6.85	1895–6	12.53	7.75	12.19	8.59
1836–7	12.30	12.60	14.30	10.30	1866–7	7.20	12.09	7.55	6.09	1896–7	7.55	12.47	14.21	10.23
1837–8	7.60	11.60	15.70	10.30	1867–8	7.24	7.71	10.01	8.48	1897–8	7.71	8.28	10.66	9.87
1838–9	11.60	17.60	11.90	6.30	1868–9	6.93	5.52	2.56	10.09	1898–9	12.31	10.11	8.66	11.45
1839–40	13.40	10.90	9.30	9.45	1869–70	7.40	7.45	5.40	5.04	1899–00	8.16	6.23	8.76	7.75
1840–1	10.75	13.20	9.70	8.40	1870–1	3.97	6.96	12.38	8.57	1900–1	5.17	12.78	13.81	6.28
1841–2	10.25	10.70	10.75	5.15	1871–2	4.24	7.56	10.33	12.31	1901–2	14.80	7.93	11.06	17.75
1842–3	7.15	10.25	14.12	16.72	1872–3	11.23	11.60	13.33	13.96	1902–3	14.90	11.02	18.54	5.27
1843–4	9.00	8.60	5.91	9.35	1873–4	6.37	9.98	8.88	7.47	1817–70	8.50	10.01	10.25	9.37
1844–5	9.49	5.55	6.96	6.46	1874–5	7.32	10.48	16.30	9.92	1871–03	9.97	10.89	12.64	9.83

Table XLVII. For the character of the record in the above table see footnote to table XLVI.

The greatest annual precipitation of the entire period of 87 years, making due allowance for the permanent differences between the Fort McHenry record and that of the U. S. Weather Bureau, was that of 1854, with a fall of 64.63. The mean annual amount for Baltimore based on the Weather Bureau observations for 33 years is 43.34 inches. The rainfall and snowfall of 1889 followed close behind that of 1854 with a

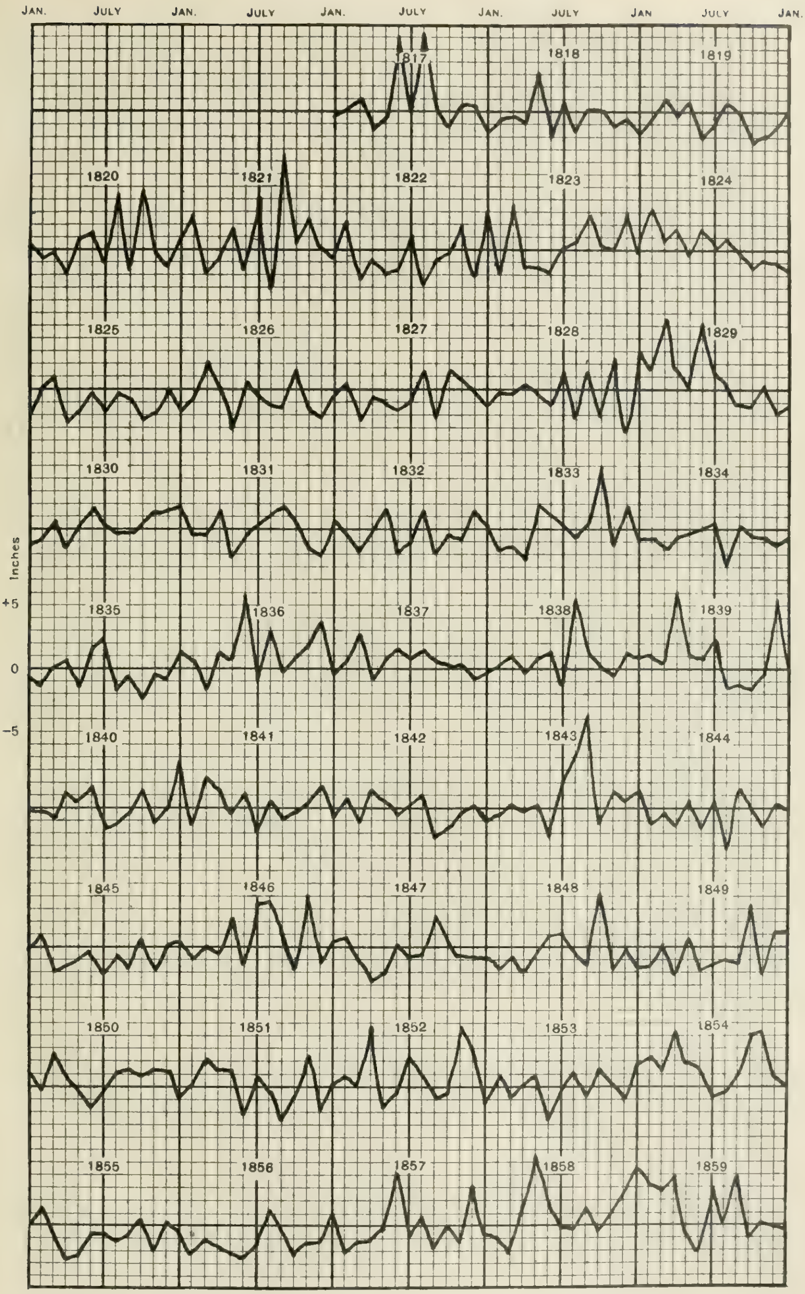


FIG. 54a.—Departures from Mean Monthly Precipitation (1817-1859).

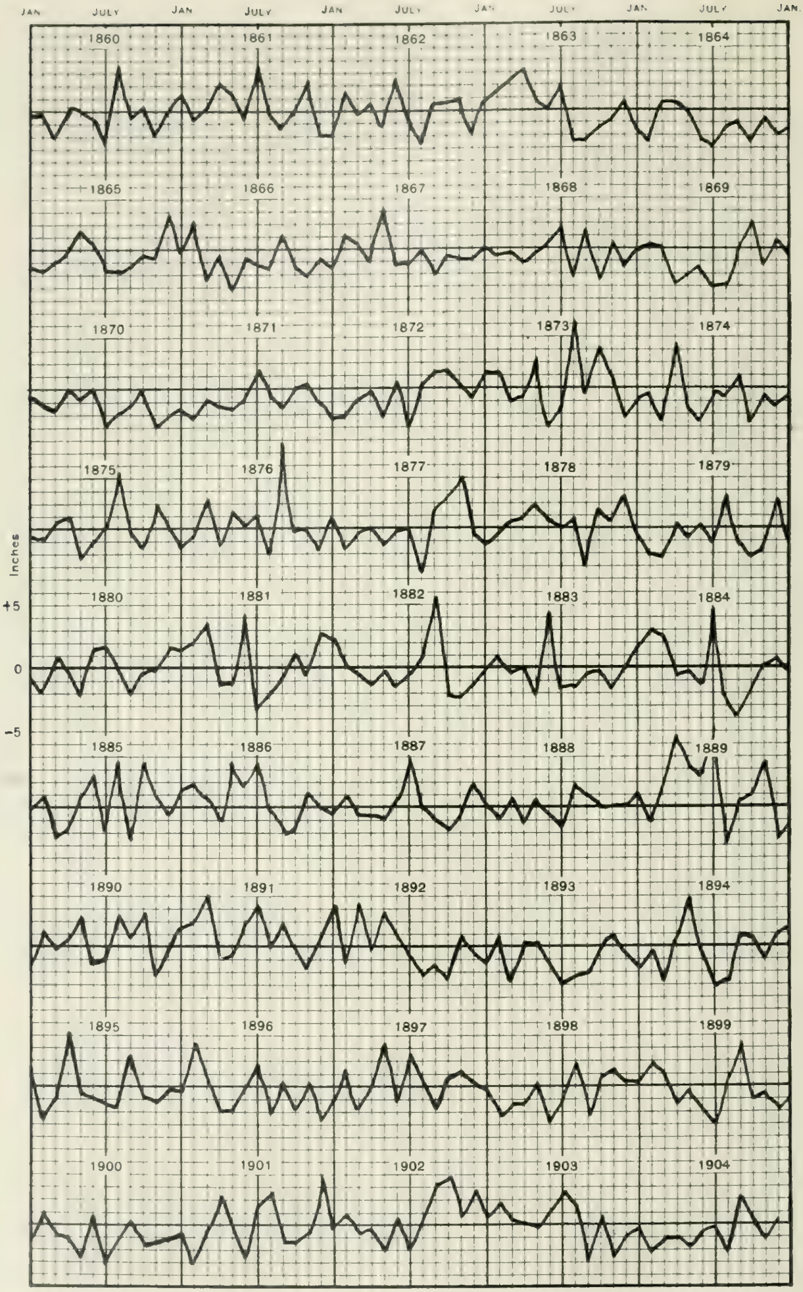
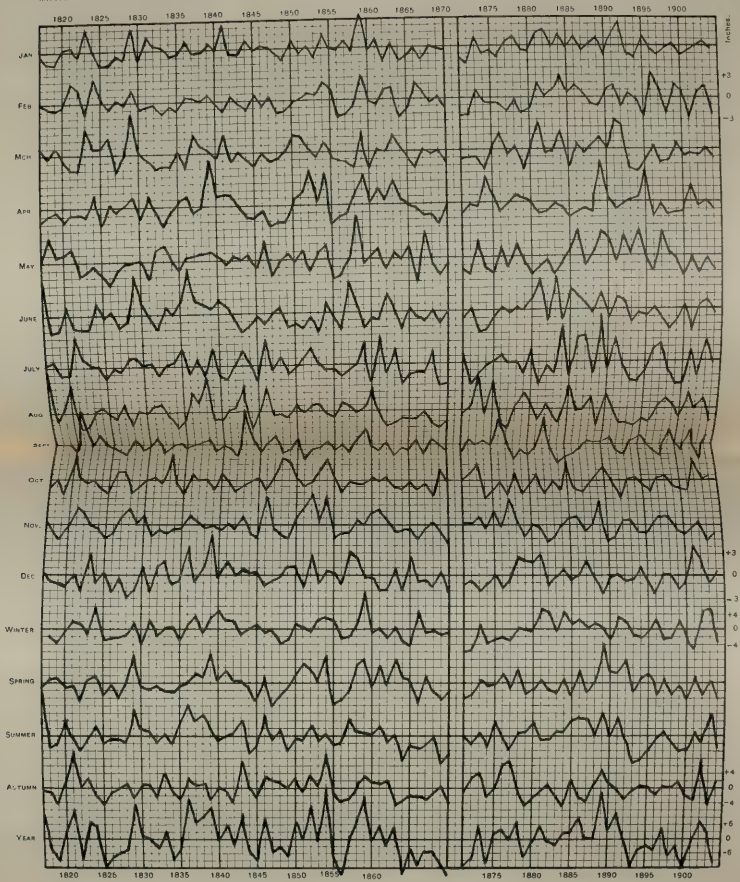


FIG. 54b.—Departures from Mean Monthly Precipitation (1860-1904).



MONTHLY, SEASONAL AND ANNUAL DEPARTURES FROM THE NORMAL PRECIPITATION (1817-1904).

total of 62.35 inches. The smallest annual precipitation recorded was 27.86 inches, reduced value, in 1870. These figures show a total range in the annual precipitation of 36.77 inches. The average departure of the annual precipitation from the normal quantity is 6.68 inches, a figure which attests the great variability of this climatic element.

If we compute from Table XLVI average annual values for each 10-year period from 1820 to 1900, we find a fairly close agreement, showing a strong tendency to return to a certain normal value in spite of great fluctuations in individual years. The most conspicuous departure is the great deficiency recorded from 1861 to 1870.

DEPARTURES OF TEN-YEAR AVERAGES FROM THE NORMAL FOR 87 YEARS.

Decades.	Departures.
1821-1830	−0.11 inches.
1831-1840	+3.13 "
1841-1850	−0.30 "
1851-1860	+3.34 "
1861-1870	−6.02 "
1871-1880	−1.98 "
1881-1890	+3.88 "
1891-1900	−2.85 "

Monthly and Annual Departures.

The chief characteristics of the monthly and seasonal departures for successive years are clearly shown in Fig. 54 and Plate X. The most conspicuous feature of these curves is the irregular, short-period fluctuations above and below the line representing the average amounts for a long series of years. The extreme irregularity in the fluctuations makes it entirely impracticable to employ this method as a basis for making long-range forecasts. When the precipitation is charted by months in regular chronological sequence, as in Fig. 54, the same characteristic fluctuations are noted. They are irregular in amount and period, but with a general tendency to return to the normal level, and with occasional evidence of a long period of excessive or deficient precipitation.

An inspection of Fig. 54 and Plate X will show at a glance that the exact average precipitation for the months, seasons or the year is an unusual occurrence. As shown in the discussion of temperatures, the arithmetical mean amount is not the most probable amount. The pre-

cipitation actually recorded is, in most cases, well above or below the normal value. The following figures show the average departure above or below the mean value, based on observations for 87 years, and disregarding the sign of the departures:

AVERAGE DEPARTURES FROM THE MEAN PRECIPITATION.

(In inches and hundredths.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Plus or minus......	1.07	1.25	1.33	1.36	1.40	1.54	1.64	1.72	1.57	1.33	1.27	1.32	6.68

The most frequent, and hence the most probable departure, differs from the figures above representing the average departure, as shown by the following table:

FREQUENCY OF PLUS AND MINUS DEPARTURES FROM THE NORMAL MONTHLY PRECIPITATION.

(In percentage of total frequency.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Plus departure ...	40	48	46	40	46	47	45	46	39	45	46	45	46
Minus departure..	60	52	54	60	53	52	54	54	61	54	54	54	54
Difference.........	20	4	8	20	7	5	9	8	22	9	8	9	8

In all months of the year the departures below the normal are in excess of those above the normal; in January, April and September as much as 20 per cent of the total number of months in 87 years. The average monthly difference is nearly 11 per cent. Hence the monthly precipitation is most likely to be below the normal amount, but the minus departures are likely to be smaller than the departures above the normal.

The most probable departures from the normal monthly amounts are indicated by the following figures:

FREQUENCY OF STATED MONTHLY DEPARTURES.

Departures (In inches).	Plus.	Minus.
0—1........................	20.0 per cent.	24.1 per cent.
1—2........................	12.3 " "	19.5 " "
2—3........................	5.1 " "	10.1 " "
3—4........................	3.8 " "	1.4 " "
4—5........................	1.8 " "	0.0 " "
5—6........................	1.0 " "	0.0 " "
6—7........................	0.4 " "	0.0 " "
7—8........................	0.2 " "	0.0 " "
	44.6 per cent.	55.1 per cent.

Excessive Rains.

The heaviest rainfall recorded in Maryland occurred at Jewell, in the southern portion of Anne Arundel County, on July 27, 1897, when the local voluntary observer measured 14.75 inches, all of which fell in the course of 18 hours, and most of it in six hours, during a severe thunderstorm.

On September 13, 1904, a storm of marked intensity developed over the Atlantic Ocean east of the coast of the South Atlantic states. It increased rapidly in intensity during the 14th and with rapid movement passed northeastward on the 14th and 15th with its center following the coast line. The precipitation in the path of the storm was of unusual intensity. The center of the cyclonic system passed just to the east of Baltimore during the night of September 14-15 accompanied by destructive winds and torrential rains. The rain began about 8 a. m. and continued with but slight interruptions until about 3 a. m. of the 15th. The total fall during these 19 hours was 5.06 inches; between 2 a. m. and 4 a. m. of the 14th, .02 inch fell, making a total fall in 24 hours of 5.08 inches. This is the greatest fall in 24 consecutive hours recorded at Baltimore since the establishment of the local office of the U. S. Weather Bureau in 1871. The greatest rate of fall during this storm occurred between 8.25 p. m. and 9.10 p. m., when 1.61 inches were recorded in 45 minutes. Some of the more interesting records of torrential rains or "cloud bursts" mentioned by Professor Henry in his report[1] on the rainfall of the United States are cited here:

"A cloud burst passed over the edge of the little town of Palmetto, Nevada, in August, 1890. A rain gauge that was not exposed to the full intensity of the storm caught 8.80 inches of water in an hour. At Tridelphia, West Virginia, 6.90 inches fell in 55 minutes on July 19, 1888. At Campo, California, 11.50 inches fell within an hour, "and some of the fall was lost!"

[1] Henry, A. J. Rainfall of the United States. Bull. D., U. S. Weather Bureau, 4to, Wash., 1897.

TABLE XLVIII.—GREATEST PRECIPITATION IN 24 CONSECUTIVE HOURS.

Year.	Jan.		Feb.		March		April		May		June		July		August		Sept.		October		Nov.		Dec.		Annual		
	Am't	Date	Am't	Date	Am't	Date	Am't	Date	Am't	Date	Am't	Date	Am't	Date	Am't	Date	Am't	Date	Am't	Date	Am't	Date	Am't	Date	Am't	Month	Date
1871......	0.40	15	0.82	1	1.06	12	0.61	28	1.20	5	0.78	17-18	2.28	27	1.41	23-24	1.01	16	1.35	6	1.62	15	0.43	20	2.28	July	27
1872......	0.40	19	0.90	2 3	0.99	9-10	1.24	8 9	0.31	2	2.37	24-25	0.62	18	1.08	15-16	1.64	26-27	2.22	24 25	1.92	6-7	0.99	19-20	2.37	June	24-25
1873......	1.57	5	1.93	15-16	1.09	20	1.06	16-17	2.16	8	0.64	28-29	1.11	27-28	4.36	13-14	1.20	13-14	3.42	19-20	1.82	23 24	0.29	1 2	4.36	Aug.	13-14
1874......	0.70	5-6	1.52	25	0.60	16-17	1.53	8-9	0.66	4-5	0.66	3-4	1.63	11-12	2.36	23-24	3.15	15-16	0.15	10	1.10	22 23	0.35	6-7	3.15	Sept.	15-16
1875......	0.73	7	1.14	11	1.57	7-8	2.64	27-28	0.78	24-25	0.85	5	2.70	15-16	1.49	12	0.87	10	2.64	27 28	1.82	23-24	0.44	24-25	2.70	July	15-16
1876......	0.78	19	1.08	14-15	2.33	24-25	1.40	3	2.36	15-16	1.28	3-4	3.14	30	0.42	25	3.94	16-17	1.41	23	0.92	19-20	0.44	29	3.94	Sept.	16-17
1877......	1.43	6-7	1.61	23 24	1.05	25-26	1.01	19-20	0.82	21	0.93	5	1.29	24-25	0.45	1-2	1.90	7-8	2.74	4	2.85	23 24	1.29	30	2.85	Nov.	23-24
1878......	0.87	10	1.71	22	2.24	11-12	1.50	27-28	1.40	14-15	2.41	17-18	2.27	29-30	1.54	16	0.49	13	2.75	22 23	1.41	27	2.85	10	2.85	Dec.	10
1879......	1.90	8-9	0.61	11-12	0.56	22-23	1.56	17-18	1.76	17-18	1.36	11-12	1.73	26	2.03	17	1.39	7-8	0.53	21 22	0.62	17-18	1.48	14	2.03	Aug.	17
1880......	0.77	27	0.59	12	0.98	27	1.85	29-30	0.59	22	2.66	11	3.71	20	1.37	25-26	1.11	9	0.85	30	1.03	4-5	1.66	4-5	3.71	July	20
1881......	1.41	9-10	1.68	18-19	3.51	8 9	0.36	13-14	0.77	18-19	2.46	8-9	0.80	13	1.01	7	1.59	11	1.42	30 31	0.87	23-24	1.73	22	3.51	Mar.	8-9
1882....	0.92	13	0.79	19	0.67	27	1.37	26-27	0.70	11 12	0.81	19	1.50	29	2.12	27-28	2.28	11	0.26	11 12	0.19	13	0.87	21	2.28	Sept.	11
1883......	0.84	13 14	1.31	10 11	1.74	10	1.32	22-23	0.57	21-22	2.66	26-27	0.76	15	1.28	29	1.33	12-13	0.80	23	0.76	26	0.85	19	2.66	June	26-27
1884.....	1.70	8-9	1.30	23	1.48	19	1.31	9	0.74	28	0.89	13-14	3.75	11	0.66	30-31	0.08	30	0.46	30	1.41	23	1.47	6	3.75	July	11
1885......	1.14	5-6	1.88	9-10	0.53	28-29	0.56	3-4	1.32	7	4.47	28	1.56	26-27	3.35	2-3	0.63	4-5	2.02	29 30	1.40	1 2	1.19	13-14	4.47	June	28
1886......	1.90	4	2.60	10-11	1.14	31	1.22	5-6	2.99	7-8	3.18	22-23	2.11	16, 21	2.21	7	0.74	15-16	0.88	26-27	1.22	12	0.81	31	3.18	June	22-23
1887......	1.02	24	1.60	18	1.22	22	0.85	18	0.78	8-9	1.43	22-23	2.77	20-21	1.76	22	0.83	11-12	0.76	20	0.80	1	1.16	10	2.77	July	20-21
1888......	0.94	1	1.06	24-25	1.64	11-12	0.89	10	1.38	23-24	1.62	27-28	1.98	9-10	2.09	5	1.15	17-18	0.80	26-27	1.14	18-19	2.56	16-17	2.56	Dec.	16-17
1889......	1.20	20-21	1.18	16	2.71	3-4	3.58	25-26	2.20	19-20	1.32	1	4.02	30-31	0.45	1	0.86	17	1.24	26-27	1.64	13	0.23	17	4.02	July	30-31
1890......	0.49	15	1.46	7-8	0.88	22	0.92	3-4	1.58	26	0.93	12	1.15	24-25	1.96	21	1.09	11	3.04	23	0.30	12-13	1.12	16 17	3.04	Oct.	23
1891......	1.44	11	1.50	21-22	1.54	27-28	1.08	11	0.90	28-29	2.05	17-18	2.59	8	1.43	24-25	4.00	5-6	1.06	22	0.51	10-11	1.16	23 24	4.00	Sept.	5-6
1892......	1.40	12-13	0.92	29	1.22	17 18	0.64	15, 22	1.85	15	1.60	27	0.81	3	0.84	2	1.24	13-14	0.24	8	1.20	15-16	1.34	13-14	1.85	May	15
1893......	0.91	1	1.21	12-13	0.53	8-9	1.03	19-20	2.30	3-4	0.64	22	1.10	8	1.02	28-29	0.65	13 14	1.60	13-14	1.60	8 9	0.65	16	2.30	May	3-4
1894......	0.99	29	1.06	25-26	0.53	22-23	1.78	10-11	1.98	6	1.01	4-5	0.47	2	0.40	19-20	1.96	18-19	1.81	9 10	0.64	3	1.51	26-27	1.98	May	6
1895.....	1.35	25-26	0.37	7-8	0.80	15 16	2.37	8	0.74	21	1.08	26-27	1.76	4-5	0.78	31	4.76	6	1.14	31	1.08	25-26	1.23	30-31	4.76	Sept.	6
1896......	1.95	23-24	3.48	5-6	1.28	15-16	0.70	1	0.44	12	1.28	16-17	2.06	21-22	0.85	10	1.46	5-6	0.81	11-12	1.21	4-5	0.21	22	3.48	Feb.	5-6
1897......	0.94	20-21	1.70	1-2	0.57	17-18	1.32	8-9	1.73	13	0.83	4-5	2.10	26-27	1.80	9 10	1.42	23	1.91	11-12	1.57	1-2	1.25	14 15	2.10	July	26-27
1898......	1.04	14-15	0.61	18-19	1.01	29-30	0.49	24	1.38	16	0.51	13	1.36	27-28	1.47	4-5	1.10	22 23	1.01	21-22	1.00	10	0.97	3 4	1.47	Aug.	4-5
1899......	0.96	6-7	1.10	12-13	1.08	4-5	1.00	7	0.83	16-17	1.05	9-10	0.69	25-26	1.86	26-27	2.90	25-26	1.67	1	0.65	3-4	0.69	23-24	2.90	Sept.	25-26
1900......	1.03	11-12	1.42	12-13	0.91	15-16	0.87	18-19	0.53	19	2.62	16-17	0.46	19-20	1.61	20-21	3.61	15-16	0.81	8	0.57	3	1.50	4	3.61	Sept.	15-16
1901......	1.37	11-12	0.50	3-4	1.55	10-11	1.83	2-3	0.80	24-25	0.49	14-15	2.00	25	3.28	6-7	0.60	2-3	1.06	13	2.04	23-24	2.88	28-29	3.28	Aug.	6-7
1902......	1.60	21-22	2.13	20-21	1.13	4-5	1.37	8	0.52	25	1.13	25-26	0.71	20	1.66	5-6	3.82	25-26	2.79	4-5	1.25	24-25	1.15	15-16	3.82	Sept.	25-26
1903......	1.59	2-3	1.74	16-17	1.44	21-22	0.99	13-14	1.76	24	1.68	11-12	3.99	12-13	1.88	27-28	0.57	17	1.13	8	0.34	4-5	1.19	19-20	3.99	July	12-13
Greatest	1.95	23 24	3.48	5-6	3.51	8-9	3.58	25-26	2.99	7-8	4.47	28	4.02	30-31	4.36	13-14	4.76	6	3.42	19 20	2.85	23-24	2.88	28-29	4.76	Sept.	6
Year.....	1896		1896		1881		1889		1886		1885		1889		1873		1895		1873		1877		1901		1895		

Table XLVIII is a record of the heaviest rainfall or snowfall in any period of 24 consecutive hours in each month from 1871 to 1903, together with the amount of the precipitation and the date of occurrence.

In his "Climates and Weather of India,"[2] Mr. H. F. Blanford cites the following, among others, as the heaviest rainfalls on record in that locality:

TORRENTIAL RAINFALLS IN INDIA.

Place.	Amount in 24 hours.	Time.
Cherra Poongee (Assam)	40.8	June 14, 1876.
Purneah (Bengal)	35.0	Sept. 13, 1879.
Nagina	32.4	Sept. 18, 1880.
Danipur	30.4	Sept. 18, 1880.
Rewah (Central India)	30.4	June 16, 1882.

In connection with the above, Mr. Blanford writes: "These excessive falls are always the result of cyclonic storms. Not such as are of destructive violence, but the long-lived cyclonic storms in which the barometer is not greatly depressed, and only recognizable in their true character when the barometer readings and the winds are laid down on the charts. . . . . Another noteworthy point is that they have frequently occurred in years of partial drought. . . . . Thus in 1875, although in the Punjab it was one of the wettest years on record, the rainfall was very deficient in Bengal and all over the southern half of the Peninsula. . . . Scarcely less remarkable is the occasional heaviness of the falls even at places where the average rainfall is not by any means excessive. That upwards of 40 inches in 24 hours should have been recorded at Cherra Poongee will perhaps hardly be surprising, but falls nearly as great, from 30 to 35 inches, in the same interval have occurred on more than one occasion on the plains of the Ganges Valley, at places where the average for the whole year is not more than from 40 to 65 inches; and even in the extremely arid province of Sind as much as 20 inches fell in one day in 1866, at Doorbaji, where the annual average is probably less than six inches."

Greatest Rainfall in 24 Hours.

In Table XLVIII the greatest precipitation in any 24 consecutive hours of each month and year from 1871 to 1903 is recorded, together with the amount of the fall and the date of occurrence. The greatest

[2] Blanford, H. F. The Climates and Weather of India, 12mo, London, 1889, pp. 77 *et seq.*

during the entire period for each month is also graphically shown in Fig. 55. Falls equalling or exceeding two inches in 24 hours have occurred in all months of the year, but the heaviest have been recorded in the summer and early fall months. The greatest fall recorded in the table, namely, 4.76 inches, was that of September 6, 1895. During the present year (1904), however, this record was broken by the excessive rainfall in connection with the severe coast storm of September 14-15, when 5.08 inches fell in 17 hours.

An inspection of Table XLVIII shows that the heaviest precipitation of the month may be very small, sometimes falling below half an inch, but such instances are comparatively infrequent, especially during the months of active plant growth. The following list comprises all months without a fall of half an inch or more in 24 hours during the 33 years from 1871 to 1903:

MONTHS WITH A MAXIMUM RAINFALL OF LESS THAN HALF AN INCH IN 24 HOURS.

January	1871, 1872, 1890.
February	1895.
March	None.
April	1881, 1898.
May	1872, 1896.
June	1901.
July	1894, 1900.
August	1876, 1877, 1889, 1894.
September	1878, 1884.
October	1874, 1882, 1884, 1892.
November	1882, 1890, 1903.
December	1871, 1873, 1874, 1875, 1876, 1889, 1896.

Fig. 55 shows the extent to which the heaviest precipitation in 24 consecutive hours occurring in each year from 1871 to 1904 has varied from year to year. The amounts range from a minimum of 1.47 inches in August, 1898, to a maximum of 5.08 inches in September, 1904. The tendency to a periodic fluctuation embracing a group of years is more marked in this diagram than in those representing the total seasonal or annual fall. Especially interesting and instructive, as well as striking, is the gradual and steady increase in the intensity of maximum rainfalls from the smallest of the entire period of 34 years in 1898 to the greatest of the period in 1904. It would seem to be a safe inference from these

facts that we have arrived at a maximum for this particular periodic swing, and that during the following two or three years there will be a diminishing intensity of precipitation in individual storms. This view finds additional confirmation in the grouping of excessive rainfalls of 2.50 inches and over as shown in Fig. 56. There seems to be no fixed relation between the annual amount of rainfall and individual rains in any given locality. Regions with a high annual or seasonal precipitation do not necessarily have excessive rates of fall for shorter periods. While some of the phenomenal rains have occurred in the tropics, where the seasonal rainfall is generally greatest, there are many instances where record-breaking downpours have occurred in comparatively dry regions.

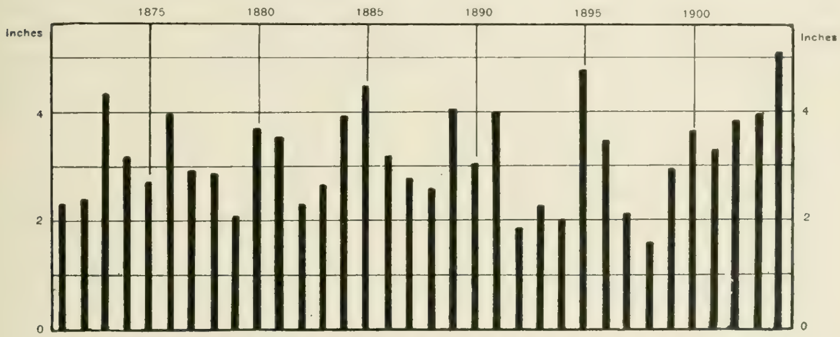


FIG. 55.—The Heaviest Precipitation in any 24 Consecutive Hours.
(Expressed in inches and fractions of an inch.)

In Table XLI will be found a record of the annual number of occasions on which the rainfall of a 24-hour period equalled certain stated amounts under and exceeding one inch. The precipitation records of the past 34 years have been further examined for all days upon which the rainfall exceeded 2.50 inches (see Table XLIX). Rainfalls of the latter amount may be considered excessive for all but a few limited regions. They are not of frequent occurrence in the vicinity of Baltimore; since 1871 there have been but 42 all told, most of which occurred in the months from June to September. Their total monthly frequency in 34 years is shown by the following figures:

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
0	2	2	1	1	5	9	3	9	6	1	3	42

In Fig. 56 their frequency and intensity are also graphically shown by months and years. The manner in which these excessive rainfalls are grouped is interesting. There are apparently three groups in the entire period of 34 years, of which the years 1876, 1887 and 1901 are the

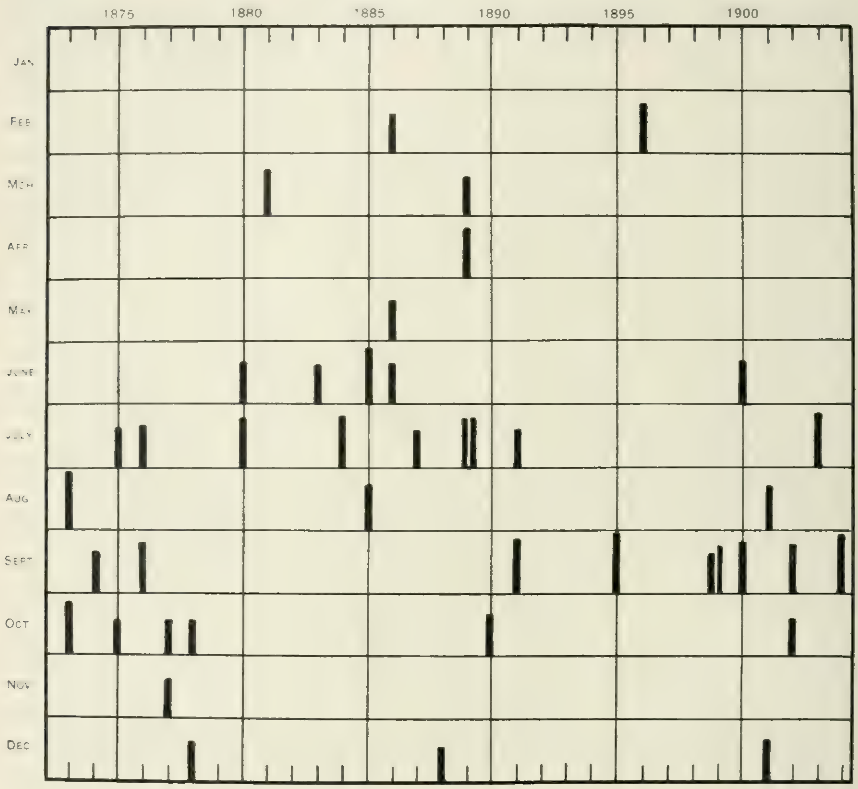


FIG. 56.—Rainfalls Equalling or Exceeding 2.50 Inches in a Day.

The frequency and seasonal distribution of rainfalls of 2.50 inches in 24 consecutive hours are shown in this diagram. The total amount of the fall is roughly indicated by the length of the heavy vertical lines, the shortest representing 2.50 inches.

central years. These years coincide with considerable exactness with the minimum sunspot period of approximately eleven years. Further attention will be given in later pages to the relation existing between rainfall and this well-known period of solar activity.

TABLE XLIX.—DATES UPON WHICH PRECIPITATION EQUALLED OR EXCEEDED 2.50 INCHES IN 24 HOURS.

January.			February.			March.			April.			May.			June.		
Year	Am't	Date	Year	Am't	Date	Year	Am't	Date	Year	Am't	Date	Year	Am't	Date	Year	Am't	Date
....	....	....	1886	2.60	10-11	1881	3.51	8-9	1889	3.58	25-26	1886	2.99	7-8	1880	2.66	11
....	....	....	1896	3.48	5- 6	1889	2.71	3-4	....	....	....	....	....	....	1883	2.66	26-27
....	....	....	....	....	....	....	...	....	....	....	....	....	....	....	1885	4.47	28
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1886	3.18	22-23
....	....	....	...	....	....	...	....	....	....	....	....	....	...	....	1900	2.62	16-17
July.			August.			September.			October.			November.			December.		
1875	2.70	15-16	1873	4.36	13-14	1874	3.15	15-16	1873	3.42	19-20	1877	2.85	23-24	1878	2.85	10
1876	3.14	30	1885	3.35	2- 3	1876	3.94	16-17	1875	2.64	27-28	....	...	....	1888	2.56	16-17
1880	3.71	20	1901	3.28	6- 7	1891	4.00	5- 6	1877	2.74	4	....	....	....	1901	2.88	28-29
1884	3.75	11	....	....	....	1895	4.76	6	1878	2.75	22-23	...	....	....	....	...	....
1887	2.77	20-21	....	....	....	1899	2.50	19-20	1890	3.04	23	....	....	....	...	....	....
1889	3.63	1- 2	....	....	....	"	2.90	25-26	1902	2.79	4- 5	....	.. .	....	....	....	....
"	4.02	30-31	....	....	....	1900	3.61	15-16	....	....	....	....	....	....	....	....	....
1891	2.59	8	....	....	....	1902	3.82	25-26	....	....	....	....	....	...	....	....	....
1903	3.99	12-13	....	....	....	1904	5.08	14-15	....	....	....	....	....	....	....	....	....

Table XLIX shows all periods of 24 consecutive hours during which rain fell to the depth of 2.50 inches or over, from 1871 to 1904. The day and year of occurrence are likewise shown, and the total amount which fell within the 24 hour period.

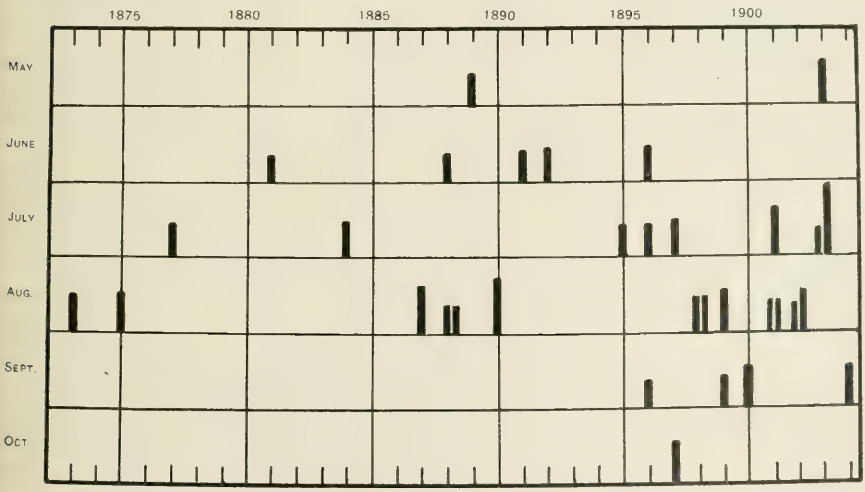


FIG. 57.—Rainfalls Equalling or Exceeding One Inch per Hour.

The frequency and seasonal distribution of rainfalls equalling or exceeding one inch in an hour are indicated in the above diagram. The exact amount of the rainfall is roughly indicated by the length of the short and heavy vertical lines. The double lines indicate the occurrence of two such falls on the same month.

A class of rainfalls of somewhat greater intensity than those just referred to in Table XLIX is shown in Table L, which contains all occurring from 1871 to 1904 in which the rate of fall equals or exceeds one inch per hour. These rains have occurred almost entirely in the warm months of the year. None are credited to January, February,

TABLE L.—DATES UPON WHICH PRECIPITATION EQUALLED OR EXCEEDED ONE INCH IN ONE HOUR.

May.				June.				July.				August.			
Year	Am't	Time	Date	Year	Am't	Time	Date	Year	Am't	Time	Date	Year	Am't	Time	Date
1889	1.20	1- 0	20	1881	1.00	0-45	20	1877	1.28	0-55	24	1873	1.30	1- 0	10
1903	1.49	0-37	24	"	1.16	1-10	20	1884	1.40	1-15	31	1875	1.41	1-15	12
....	....	....	....	1888	1.10	0-35	23	1895	1.05	1- 0	5	1887	1.74	1-10	22
....	....	....	....	1891	1.15	1- 0	4	1896	1.20	1- 0	21	1888	1.03	1- 0	8
....	....	....	....	1892	1.23	1- 0	27	1897	1.36	0-23	17	"	1.12	1- 0	5
....	....	....	....	....	....	....	....	1901	1.77	0-25	25	1890	1.96	1-10	21
....	....	....	....	....	....	....	....	1903	2.87	0-33	12	1898	1.42	0-25	1
September.				October.				"	1.00	0-24	30	"	1.20	0-47	4-5
								....	....	....	....	1899	1.59	1- 0	26
								....	....	....	....	1901	1.00	0-44	6
1896	1.00	0-40	19	1897	1.38	1- 0	12	....	....	....	....	"	1.06	0-35	12
1899	1.00	0-53	25	....	....	....	....	....	....	....	....	1902	1.40	0-39	5-6
1900	1.62	1- 0	15	....	....	....	....	....	....	....	....	"	1.22	0-25	27
1904	1.48	0-40	14	....	....	....	....	....	....	....	....	....	....	....	....

Table L is a list of all occurrences of rainfall equalling or exceeding one inch in one hour, from 1871 to 1904. The year, month and day of occurrence are shown, and also the amount recorded and the duration of the excessive rate of rainfall; the latter in the column marked "Time," expressed in hours and minutes.

March, April, November or December. The distribution through the season is as follows:

May	June	July	Aug.	Sept.	Oct.	Year
2	5	8	13	4	1	33

The monthly distribution here indicated associates this class of excessive rainfalls at once with the thunderstorm. Their frequency and intensity, arranged by months and years, are also graphically shown in Fig. 57. The grouping referred to above in the discussion of the rainfalls of 2.50 inches and over is here also evident, though less clearly.

Excessive Rates of Precipitation.

The rate of rainfall, or the quantity which falls per hour, or part of an hour, in the case of excessive precipitation, is one of great importance in large centers of population, as it involves the engineering problem of providing adequate means for carrying off the surplus water without damage to property or interruption to traffic. Especially is it desirable in this connection to know the maximum rate of fall. Hence particular pains have been taken to tabulate and chart excessive rainfalls under a variety of conditions. To facilitate the study of such practical problems in engineering, Table LI has been prepared, showing all the necessary

TABLE LI.—EXCESSIVE RATES OF RAINFALL IN CUMULATIVE FIVE-MINUTE PERIODS.

Year.	Day.	Total duration. Beginning.	Total duration. Ending.	Total amt.	Excessive rate. Beginning.	Excessive rate. Ending.	Amt. before ex. rate.	Excessive periods in minutes. 5	10	15	20	25	30	35	40	45	50	60	80	..
January.																				
1895.	26	25th 6.45p	7.20a	1.35	3.30a	3.52a	0.70	.05	.10	.25	.45	..	..	..	..	..	..	..	..	..
March.																				
1899.	12	8.15p	8.55p	.34	8.23p	8.29p	.01	.01	.26	.29	..	..	..	..	..	..	..	..	.	...
May.																				
1894.	6	6.55p	7.30p	.25	7.00p	7.04p	T	.25	..	..	..	..	..	..	..	..	..	..	..	√
"	"	8.10p	DN	1.47	8.45p	8.57p	.20	.20	.35	.40	..	..	..		..	..	..	..	..	√
"	"	8.10p	DN	1.47	10.05p	10.27p	.60	.20	.30	.45	.55	.60	..	..	..	..	..	..	..	√
"	20	8.20p	21st 9.15a	1.53	9.22p	9.54p	T	.15	.15	.30	.30	.40	.45	.55	..	..	..	..	..	..
"	"	8.20p	21st 9.15a	1.53	10.52p	11.06p	.60	.15	.35	.40	..	..	..	..	..	..	..	..	..	..
1894.	23	11.15a	12.30p	.80	12.00n	12.25p	.05	.20	.45	.60	.70	.75	..	..	..	..	..	..	..	√
1897.	21	1.43p	2.35p	.72	1.49p	2.00p	.01	.57	.67	.70	.71	..	..	..	..	..	..	..	..	√
"	24	6.25p	9.15p	.85	6.46p	7.01p	.01	.11	.29	.42	.44	..	..	..	..	..	..	..	..	√
1898.	16	4.08p	6.09p	1.20	5.09p	5.39p	.24	.29	.57	.59	.59	.66	.82	.84	..	..	..	..	..	..
1899.	16	6.50p	8.20p	.74	7.08p	7.26p	T	.23	.42	.51	.53	..	..	..	..	..	..	..	..	√
1901.	24	10.15p	DN	.62	10.25p	10.40p	.01	.11	.30	.47	.48	..	..	..	..	..	..	..	..	√
1902.	25	5.35p	6.20p	.51	5.37p	5.52p	T	.27	.40	.45	.47	..	..	..	..	..	..	..	..	√
1903.	24	2.30a	4.20a	1.63	2.53a	3.30a	.03	.21	.58	.80	.87	.93	1.22	1.44	1.51	1.54	..	..	..	√
		Duration. h. m.			Duration. h. m.															
Aver..		3-45		1.02	0-19		.13	.23	.40	.51	.56	.67	.83	.94	1.51	1.54	..	..	..	..
Great.		12-55		1.63	0-37		.60	.57	.67	.80	.87	.93	1.22	1.44	1.51	1.54	..	..	..	..

TABLE LI CONT.—EXCESSIVE RATES OF RAINFALL IN CUMULATIVE FIVE-MINUTE PERIODS.

Year.	Day.	Total duration. Beginning.	Total duration. Ending.	Total amt.	Excessive rate. Beginning.	Excessive rate. Ending.	Amt. before ex. rate.	5	10	15	20	25	30	35	40	45	50	60	80	..
								JUNE.												
1894.	12	4.28p	5.00p	0.47	4.40p	4.54p	T	.32	.42	.47	..	..	..	..	..	..	..	..	..	
"	24	4.10p	6.30p	.70	4.57p	5.08p	T	.25	.35	.40	..	..	..	..	..	..	..	..	..	
1895.	27	3.00p	7.35p	.65	3.02p	3.08p	T	.25	.30	..	..	..	..	..	..	..	..	..	..	
1896.	8	4.04p	6.20p	.95	4.07p	4.36p	T	.30	.50	.65	.80	.85	.90	..	..	..	..	..	..	
"	16	4.17p	7.03p	1.21	4.20p	4.40p	T	.35	.55	.65	.70	..	..	..	..	..	..	..	..	
1896.	21	4.47p	5.25p	.45	4.56p	5.14p	T	.25	.35	.40	.45	..	..	..	..	..	..	..	..	
1897.	4	4.33p	5th 8.18a	.82	4.48p	5.05p	.05	.16	.40	.49	.50	..	..	..	..	..	..	..	..	
"	25	3.50p	4.07p	.30	3.53p	4.03p	T	.10	.30	..	..	..	..	..	..	..	..	..	..	
1900.	14	4.10p	8.10p	.62	4.20p	4.40p	T	.04	.10	.36	.52	.58	..	..	..	..	..	..	..	
1902.	7	2.13p	4.55p	.88	2.13p	2.43p	0	.13	.23	.35	.60	.75	.87	..	..	..	..	..	..	
1902.	25	6.27p	26th 4.00a	1.13	11.25p	11.50p	.33	.15	.22	.30	.45	.53	.56	..	..	..	..	..	..	
1903.	6	8.20p	7th 7.10a	1.05	1.46a	2.04a	.25	.10	.24	.33	.40	..	..	..	..	..	..	..	..	..
"	8	3.03p	3.45p	.73	3.18p	3.35p	T	.32	.54	.70	.73	..	..	..	..	..	..	..	..	
		Duration. h. m.			Duration. h. m.															
ver..		4-23		.75	0-18		.05	.21	.35	.46	.57	.68	.78	..	..	..	..	..	..	..
reat.		15-45		1.21	0-30		.33	.35	.55	.70	.80	.85	.90	..	..	..	..	..	..	..
								JULY.												
1894.	6	3.35p	5.00p	.44	4.41p	4.50p	T	.25	.40	..	..	..	..	..	..	..	..	..	..	
1895.	5	12.30p	1.30p	1.05	12.21p	12.46p	T	..	.69	.84	.94	.99	.99	.99	.99	1.04	..	..	..	
"	16	4.30p	4.55p	.66	4.33p	4.52p	T	.20	.50	.60	.66	..	..	..	..	..	..	..	..	
1896.	4	10.23p	5th 5.10a	.33	10.28p	10.32p	T	.27	..	..	..	..	..	..	..	..	..	..	..	..
"	7	12.25p	12.55p	.50	12.26p	12.42p	T	.20	.40	.45	.50	..	..	..	..	..	..	..	..	
1896.	12	7.25p	7.43p	.49	7.28p	7.36p	T	.25	.45	..	..	..	..	..	..	..	..	..	..	
"	21	9.15p	22nd 1.50a	2.05	9.19p	10.39p	T	.25	.35	.45	.60	.65	.65	.70	.75	.85	.95	1.20	1.80	..
"	27	7.45p	8.38p	.56	8.11p	8.24p	T	.30	.45	.45	..	..	..	..	..	..	..	..	..	
1897.	12	2.10p	3.25p	.30	2.17p	2.23p	.03	.25	.26	..	..	..	..	..	..	..	..	..	..	
"	17	12.25p	5.40p	1.76	3.28p	3.48p	.38	.26	.66	1.05	1.17	..	..	..	..	..	..	..	..	
1898.	19	1.45p	4.25p	1.01	2.07p	2.35p	.01	.12	.36	.58	.81	.91	.95	..	..	..	..	..	..	
"	20	8.25p	DN	.51	8.30p	8.44p	.01	.15	.34	.50	..	..	..	..	..	..	..	..	..	
"	28	2.17p	3.15p	.88	2.23p	2.43p	.01	.37	.66	.79	.86	..	..	..	..	..	..	..	..	
1901.	25	6.00p	7.00p	1.95	6.00p	6.35p	0	.31	.80	1.18	1.54	1.77	1.85	1.91	1.94	..	..	..	..	
1902.	20	1.27p	1.55p	.56	1.29p	1.42p	T	.31	.50	.55	.56	..	..	..	..	..	..	..	..	
1903.	12	12.01p	1.10p	2.87	12.04p	12.37p	T	.33	.98	1.72	2.23	2.52	2.69	2.87	..	..	..	..	..	
"	"	5.40p	7.50p	1.02	6.20p	6.40p	.04	.34	.54	.61	.71	.72	..	..		..	..	..	..	
"	30	4.10p	6.10p	1.04	4.33p	4.55p	T	.03	.18	.64	.93	1.00	..	..	..	..	..	..	..	
		Duration. h. m.			Duration. h. m.															
Aver..		1-56		1.00	0-21		.03	.25	.50	.74	.88	1.22	1.43	1.62	1.23	.94	.95	1.20	1.80	..
Great.		6-47		2.87	1-20		.38	.37	.98	1.72	2.23	2.52	2.69	2.87	1.94	1.04	.95	1.20	1.80	.

TABLE LI CONT.—EXCESSIVE RATES OF RAINFALL IN CUMULATIVE FIVE-MINUTE PERIODS.

Year.	Day.	Total duration. Beginning.	Total duration. Ending.	Total amt.	Excessive rate. Beginning.	Excessive rate. Ending.	Amt. before ex. rate.	Excessive periods in minutes. 5	10	15	20	25	30	35	40	45	50	60	80
								AUGUST.											
1895	31	4.18p	5.00p	.78	....	....	0	..	..	..	..	..	..	..	..	.78	..	..	..
1897	9-10	11.30p	5.10a	1.60	1.30a	2.20a	.40	.03	.07	.12	.19	.25	.42	.52	.62	.77	.82	..	..
"	23	11.03a	11.58a	.74	11.33a	11.55a	.02	.14	.24	.48	.71	..	..	..	..	..	..	..	..
"	25-6	9.50p	1.10a	.83	11.26p	11.37p	.24	.23	.36	.37	..	..	..	..	..	..	..	..	..
1898	1	3.10p	4.00p	1.44	3.15p	3.40p	T	.46	.78	1.16	1.36	1.42	..	..	..	..	..	..	..
1898	4-5	11.40p	DN	1.47	11.50p	12.25a	.03	.05	.29	.48	.78	.94	1.02	1.09	1.12	1.17	..	..	..
1899	13	2.15p	2.40p	.53	2.18p	2.33p	T	.23	.43	.52	.53	..	..	..	..	..	..	..	..
"	21	7.29p	9.10p	.78	8.10p	8.24p	.35	.21	.32	.38	.39	..	..	..	..	..	..	..	..
"	26	8.10p	DN	1.63	8.15p	9.00p	T	.04	.25	.49	.60	.82	1.00	1.39	1.51	1.56	..	..	..
1900	16	2.20a	3.00a	.36	2.21a	2.30a	T	.18	.32	.34	..	..	..	..	..	..	..	..	..
1900	21	DN	7.30p	1.48	5.47a	6.20a	.25	.10	.37	.58	.72	.85	.91	.93	.94	.97	1.00	1.06	..
1901	6	DN	12.25p	2.05	11.15a	11.45a	1.08	.05	.09	.32	.56	.77	.92	..	..	..	..	..	..
"	12	10.37a	2.05p	1.43	11.45a	12.20p	.09	.06	.10	.31	.43	.78	1.00	1.10	..	..	..	..	..
"	27	6.35p	7.30p	.81	6.40p	6.55p	.02	.30	.62	.76	.78	..	..	..	..	..	..	..	..
1902	3	9.30p	9.50p	.66	9.33p	9.43p	T	.30	.64	.66	..	..	..	..	..	..	..	..	..
1902	5-6	11.40p	DN	1.43	11.46p	16.25a	.01	.10	.30	.49	.56	.64	.89	1.24	1.40	..	..	..	..
"	11	3.11p	4.05p	.55	3.46p	3.58p	.14	.17	.35	.41	..	..	..	..	..	..	..	..	..
"	27	4.29p	5.30p	1.27	4.37p	5.02p	T	.10	.47	.89	1.12	1.22	1.24	..	..	..	..	..	..
1903	26	9.45a	10.35p	.52	9.53p	10.11p	T	.11	.37	.49	.52	..	..	..	..	..	..	..	..
"	27-28	11.45p	8.05a	1.53	4.30a	4.41a	.98	.03	.27	.49	.50	..	..	..	..	..	..	..	..
		Duration. h. m.			Duration. h. m.														
Aver...		2-48		1.09	0-24		.18	.15	.35	.51	.65	.85	1.23	1.25	1.12	1.05	.91	1.06	..
Great..		12-50		2.05	0-50		1.08	.46	.78	1.16	1.36	1.42	1.24	1.39	1.51	1.56	1.00	1.06	..
								SEPTEMBER.*											
1894	8	1.27p	1.55p	.50	1.42p	1.51p	T	.20	.50	..	..	..	..	..	..	..	..	..	..
1896	3	2.46p	3.43p	.36	2.46p	2.57p	T	.10	.30	.35	..	..	..	..	..	..	..	..	..
"	19	4.56p	5.55p	1.05	5.15p	5.39p	T	.30	.65	.90	1.00	1.05	..	..	..	..	..	..	..
1897	16-7	10.38p	1.15a	.71	10.45p	10.56p	T	.20	.39	.43	..	..	..	..	..	..	..	..	..
1898	26	6.20p	6.45p	.35	6.20p	6.35p	T	.14	.31	.35	..	..	..	..	..	..	..	..	..
1899	2	5.30a	8.25a	.59	5.54a	6.14a	.02	.13	.26	.39	.48	.50	..	..	..	..	..	..	..
"	25	5.20p	8.05p	2.15	5.42p	6.20p	.11	.09	.21	.28	.40	.53	.75	.87	.90	.92	..	..	..
1900	15	1.20p	DN	3.61	10.45p	11.30p	1.87	.18	.60	.86	1.02	1.18	1.32	1.46	1.49	1.55	1.58	1.61	..
		Duration. h. m.			Duration. h. m.														
Aver...		1-35		1.16	0-22		.25	.17	.40	.51	.72	.82	1.04	1.16	1.20	1.24	1.58	1.61	..
Great..		2-55		3.61	0-45		1.87	.30	.65	.90	1.02	1.18	1.32	1.46	1.49	1.55	1.58	1.61	.
								OCTOBER.											
1897.	12	5.35a	10.05a	1.92	6.59a	8.00a	.14	.17	.26	.31	.48	.52	.67	.82	.92	1.05	1.21	1.35	1.45
1900.	8	12.45p	1.35p	.40	12.54p	1.05p	T	.20	.36	.38	..	..	..	..	..	..	..	..	..
1903.	8	9.10a	2.05p	1.07	9.11a	9.16a	T	.25	..	..	..	..	..	..	..	..	..	..	..
		Duration. h. m.			Duration. h. m.														
Aver..		3-25		1.13	0-26		.05	.21	.31	.34	.48	.52	.67	.82	.92	1.05	1.21	1.35	1.45
Great.		4-55		19.2	1-01		.14	.25	.36	.38	.48	.52	.67	.82	.92	1.05	1.21	1.35	1.45

* Sept. 6, 1895, rain began 2.10 a. m., ended 6.45 p. m., amount 4.76 inches. The gauge was not working, hence only stick measurements were possible, and it is estimated that 1.06 inches rain fell between 4.00 and 6.00 p. m.

TABLE LI CONT.—EXCESSIVE RATES OF RAINFALL IN CUMULATIVE FIVE-MINUTE PERIODS.

Year.	Day.	Total duration. Beginning.	Total duration. Ending.	Total amt.	Excessive rate. Beginning.	Excessive rate. Ending.	Amt. before ex. rate.	5	10	15	20	25	30	35	40	45	50	60	80	..
							NOVEMBER.													
1895.	26	1.35p	4.45p	.98	3.00p	4.00p	.03	..	..	..	..	..	..	..	..	..	..	.93	..	..

Table LI contains a complete list of all occurrences of excessive rainfall from 1894 to 1903, arranged according to months and years. The scale of excessive rates of precipitation adopted by the U. S. Weather Bureau, and employed in the above classification, is shown in the text. The above table shows the year, month and day of occurrence of the excessive rainfall, the time of the beginning and ending of the entire rain period, and also of the period of excessive rate of fall, the total amount of fall, and the cumulative amounts which fell in the successive 5-minute periods. The symbol (√) in the last column indicates the occurence of a thunderstorm in connection with the rainfall; ·.· indicates the occurrence of a thunderstorm on the same day at some other hour.

details of every instance of excessive rate at Baltimore occurring since 1893, at which time the automatically recording raingage was installed at the Baltimore office.

The arrangement is by months and years and shows the following facts: the year, the day and hour of occurrence, the total amount of the rainfall during the entire progress of the storm, the time of beginning and ending of the excessive rate of fall, the amount of rainfall before

TABLE LII.—SUMMARY OF EXCESSIVE RATES OF PRECIPITATION IN CUMULATIVE FIVE-MINUTE PERIODS.

	Excessive rains. No.	Excessive rains. Duration.	Excessive rains. Am'ts.	Duration of excessive rate.	Excessive periods. 5	10	15	20	25	30	35	40	45	50	60	80
					AVERAGES.											
		h. m.	in.	min.												
January	1	12-35	1.35	22	.05	.10	.25	.45	..	..	..	..	..	..	..	..
March	1	0-40	.34	6	.01	.26	.29	..	..	..	..	..	..	..	..	..
May	13	3-45	1.02	19	.23	.40	.51	.56	.67	.83	.94	1.51	1.54	..	..	..
June	13	4-23	.75	18	.21	.35	.46	.57	.68	.78	..	..	..	..	..	..
July	18	1-56	1.00	21	.25	.50	.74	.88	1.22	1.43	1.62	1.23	.94	.95	1.20	1.80
August	20	2-48	1.09	24	.15	.35	.51	.65	.85	1.23	1.25	1.12	1.05	.91	1.06	..
September	8	1-35	1.16	22	.27	.40	.51	.72	.82	1.04	1.16	1.20	1.24	1.58	1.61	..
October	3	3-25	1.13	26	.21	.31	.34	.48	.52	.67	.82	.92	1.05	1.21	1.35	1.45
November	1	3-10	.98	..	..	..	..	..	..	..	..	..	..	..	.93	..
Average	78	3-49	.98	20	.16	.33	.45	.62	.79	1.00	1.16	1.20	1.16	1.16	1.23	1.62

TABLE LII CONT.—SUMMARY OF EXCESSIVE RATES OF PRECIPITATION IN CUMULATIVE FIVE-MINUTE PERIODS.

	Excessive rains. No.	Duration.	Am'ts.	Duration of excessive rate.	Excessive periods. 5	10	15	20	25	30	35	40	45	50	60	80
					GREATEST.											
		h. m.	in.	h. m.												
January		12-35	1.35	0-22	.05	.10	.25	.45	..	..	..	..	..	..	..	..
March		0-40	.34	0-6	.01	.26	.29	..	..	..	..	..	..	..	..	..
May		11-55	1.63	0-37	.57	.67	.80	.87	.93	1.22	1.44	1.51	1.54	..	..	..
June		15-45	1.21	0-30	.35	.55	.70	.80	.85	.90	..	..	..	..	..	..
July		6-47	2.87	1-20	.37	.98	1.72	2.23	2.52	2.69	2.87	1.94	1.04	.95	1.20	1.80
August		12-50	2.05	0-50	.46	.78	1.16	1.36	1.42	1.24	1.39	1.51	1.56	1.00	1.06	..
September		2-55	3.61	0-45	.30	.65	.90	1.02	1.18	1.32	1.46	1.49	1.55	1.58	1.61	..
October		4-55	1.92	1-01	.25	.36	.38	.48	.52	.67	.82	.92	1.05	1.21	1.35	1.45
November		3-10	.98	..	..	..	..	..	..	..	..	..	..	..	.93	..
Greatest		15-45	2.87	1-20	.57	.98	1.72	2.23	2.52	2.69	2.87	1.94	1.56	1.58	1.61	1.80
Year		..	..	..	1897	1903						1901	1899	1900		1896
Month		..	..	..	May.	July						July.	Aug.	Sept.		July.
Day		..	..	..	21	12						25	26	15		21
Hour of beginning		..	..	..	1.49p	12.04 p. m.						6.00p	8.15p	10.45p		9.19p

Table LII contains a summary of facts contained in Table LI.

the excessive rate began, and the amounts recorded in cumulative five-minute periods during the continuance of the excessive rate. When the rain fell in connection with a thunderstorm this fact is also noted. It is a matter of record that in almost every instance these excessive rainfalls occur in connection with thunderstorms. In Table LII there is a summary of the preceding table, containing the average amounts recorded during cumulative 5-minute periods, and also the greatest amount for the same intervals during the entire period of ten years. The average and maximum rates of precipitation are also shown graphically for the entire year in Fig. 58.

Excessive rates of rainfall as defined by the U. S. Weather Bureau, and employed in its published records, are indicated in the following table:

TABLE OF RATES CONSIDERED EXCESSIVE.

Amount.	Time.	Amount.	Time.
0.25 inch in	5 minutes.	0.60 inch in	40 minutes.
0.30 " "	10 "	0.65 " "	45 "
0.35 " "	15 "	0.70 " "	50 "
0.40 " "	20 "	0.75 " "	60 "
0.45 " "	25 "	0.80 " "	80 "
0.50 " "	30 "	0.90 " "	100 "
0.55 " "	35 "	1.00 " "	120 "

An inspection of Table LI will show that excessive rates of fall as defined above are confined almost entirely to the warm months of the

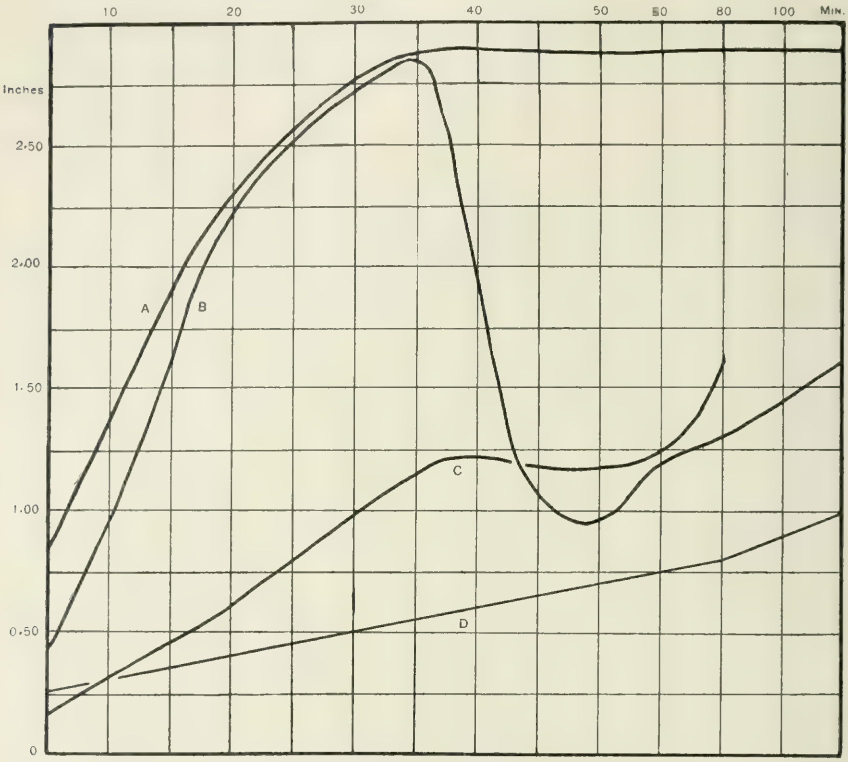


FIG. 58a.—Excessive Rates of Rainfall.

A. The curve A represents the maximum rate of precipitation attained in any consecutive 5, 10, 15, etc., minutes during the heavy rainstorm of July 12, 1903.

B. Represents the rate during the first 5, 10, 15, etc., minutes after the beginning of the excessive precipitation of the storm of July 12, 1903.

C. Represents the average rate in 78 cases of excessive rates of fall.

D. Represents the lower limits of rates considered excessive by the U. S. Weather Bureau.

year. Of a total of 84 instances recorded in eleven years, the seasonal distribution is as follows:

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1	0	1	0	13	14	19	21	9	5	1	0	84

Over 90 per cent of all occurrences are credited to the months of May to September. None have been recorded in February, April and Decem-

ber, while January, March and November have but one each. Over 90 per cent of all excessive rains have occurred in connection with thunderstorms in the immediate vicinity of the station of observation. The average rate of fall based upon all excessive rains during a period of 10 years is indicated by the following figures for the five-minute cumulative intervals from 5 to 80 minutes.

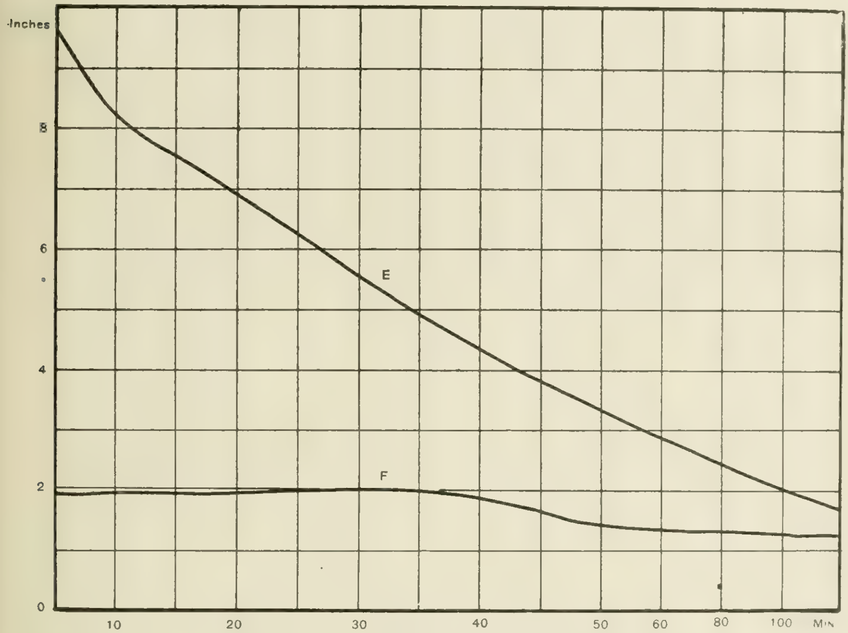


FIG. 58b.—Excessive Rates of Rainfall.

E. Represents the rate of precipitation per hour during the heaviest 5, 10, 15, etc., minutes of rainfall in the storm of July 12, 1903.

F. Represents the average rate per hour for 78 cases of excessive rates of fall.

AVERAGE AMOUNTS OF EXCESSIVE RAINFALL.

(In inches and hundredths.)

	Number of minutes from beginning of excessive rate.											
	5	10	15	20	25	30	35	40	45	50	60	80
Amount of fall........	.16	.33	.45	.62	.79	1.00	1.16	1.20	1.16	1.16	1.23	1.62

Selecting from Table LII the maximum rate of fall for each of the periods indicated, irrespective of the month in which it occurred, we have the figures below, which represent the maximum observed rates for the first 5, 10, 15, etc., minutes after the beginning of the excessive rate of fall.

15

MAXIMUM RATES OF RAINFALL.

	Minutes.											
During first.........	5	10	15	20	25	30	35	40	45	50	60	80
Amount of fall.......	.57	.98	1.72	2.23	2.52	2.69	2.87	1.94	1.56	1.58	1.61	1.80
Month................	May	July						July	Aug.	September		July
Year.................	1897	1903						1901	1899	1900		1896

The destructive storm of July 12, 1903, which swept over Baltimore and vicinity, was accompanied by a downpour, the rate of which was probably never equaled in the annals of Baltimore weather. The rate of precipitation as measured at the local office of the U. S. Weather Bureau is indicated by the following figures, and graphically shown in Fig. 58:

RATE OF RAINFALL IN STORM OF JULY 12, 1903.

For any period of	Amount.	Rate per hour.
5 consecutive minutes.........	0.80 inches.	9.60 inches.
10 " "	1.35 "	8.10 "
15 " "	1.92 "	7.68 "
20 " "	2.32 "	6.96 "
25 " "	2.58 "	6.19 "
30 " "	2.75 "	5.50 "
40 " "	2.87 "	4.31 "
50 " "	2.87 "	3.44 "
60 " "	2.87 "	2.87 "
120 " "	2.87 "	1.44 "

Table LII, Maximum Cumulative 5-Minute Periods, shows a different value, namely, the precipitation of the *first period* of 5, 10, 15, 20, etc., minutes *after the beginning of the excessive rate of fall.* The storm of July 12, 1903, showed a maximum rate for every period from 5 minutes to one hour.

A rough calculation has been made of the amount of water which fell within the limits of Baltimore City during the storm of July 12, 1903. It was probably one of the most severe storms ever witnessed in the city. While the area of destruction in this type of storm is fortunately of extremely limited extent, it may be safely assumed that practically all of the city had a rainfall approximately equalling the amount recorded by the official gage. The central path of the storm was about a mile distant from the office of the Weather Bureau; nearer the center of the path the rainfall was probably heavier than in portions of the city beyond its area of destructive winds. Hence we may assume the officially recorded

fall to be a safe estimate of the average for the entire city. Assuming the area of Baltimore City to be 31.15 square miles, we may readily compute the amount of water which fell during the progress of the storm:

WEIGHT OF RAINFALL IN STORM OF JULY 12, 1903.
(Within the limits of Baltimore City.)

During the first	Depth of fall.	Gallons per acre.	Tons within City Limits.
5 minutes.........	.33 inch.	7,466	745,428
10 "	.98 "	22,172	2,213,696
15 "	1.72 "	38,913	3,885,162
30 "	2.69 "	60,859	6,076,369
35 "	2.87 "	64,931	6,482,967
During the heaviest 5-minute fall	0.80 "	18,099	1,807,098

Frequency of Consecutive Days with Rain or Snow.

In a large percentage of instances when rain or snow falls, it is confined to a single day. The exact percentage depends largely upon what is regarded as a day with rain. Including a light sprinkling rain, or a flurry of snow, in our calculations we find that in the past 33 years, the precipitation was confined to one day in 36 per cent of the total number of days with rain or snow. Considering only measurable quantities of precipitation (0.01 inch or more) the percentage is increased to 45. In 28 per cent of all cases the rain or snow extended into two consecutive days, and in 16 per cent, three days, when we take account of "traces." Counting only appreciable quantities, the percentages are respectively 31 and 13. The instances of precipitation on more than three days decrease rapidly with each successive day added. In the table below, the frequency, *excluding* "traces" of rain or snow, is shown for each month and for the entire year to the maximum period, namely, 14 days.

FREQUENCY OF CONSECUTIVE DAYS WITH RAIN OR SNOW.
(Expressed as percentages of the total number of cases of appreciable rainfall in 33 years.)

Days.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1	42	41	42	38	46	47	49	49	49	37	40	54	45
2	35	35	29	32	28	33	26	30	27	40	35	26	31
3	12	13	16	18	7	11	15	7	14	13	17	10	13
4	7	8	6	6	10	4	5	7	5	8	5	4	6
5	2	1	3	4	4	3	3	3	3	2	1	3	3
6	2	1	2	1	2	2	1	2	..	..	1	1	1
7	..	1	1	1	..	..	..	..	1	1	1	1	0.4
8	1	..	..	1	..	..	..	..	..	..	..	..	0.1
9	..	..	..	..	1	..	1	..	1	..	..	1	0.2
10	..	..	1	..	..	..	..	..	..	..	..	1	0.1
11	..	1	..	..	..	..	..	..	..	..	..	..	0.0
12	..	..	..	..	..	..	..	..	..	..	..	.	0
13	..	..	..	..	1	..	..	..	..	..	..	..	0.1
14	..	..	..	..	..	..	..	1	..	..	..	..	0.0

Including days with "traces" of precipitation, the annual frequency is indicated by the following figures:

ANNUAL FREQUENCY OF CONSECUTIVE DAYS WITH RAIN OR SNOW.
(Including "traces.")

Number of days...	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Percentage of possible occurrence.	36	28	16	9	5	2.5	0.9	0.9	0.4	0.2	0.3	0.1	0.0	0.1

In the past 33 years there has been no single instance of rain or snow on more than 14 consecutive days, and but few in which the rain occurred on more than six consecutive days. There have been longer periods of "unsettled weather," but these will be found, upon investigation, to have been interrupted by one or more days without even a "trace" of rain. (See Table LIV, Wet Spells.)

Dry Spells.

While the rainfall is quite evenly distributed throughout the year, there are at times periods of many days without appreciable precipitation, or at least of amounts insufficient for the requirements of plant growth. During some seasons of the year this scarcity of rain is of comparatively little importance; during periods of critical crop growth, however, it becomes a question of serious moment. What constitutes a dry spell is largely a matter of arbitrary judgment. It is not alone the number of days without rain; pre-existing conditions enter largely into the problem, as well as the stage of development of vegetation. In the classification of dry spells noted in Table LIII, the selection includes, as a lower limit, all periods exceeding two weeks during which the precipitation was less than one-tenth of an inch. While this limit is a purely arbitrary one, a period of 14 days with either no rain or less than one-tenth of an inch is a long interval considering the average frequency of rains in this vicinity. For periods longer than two weeks, a proportionately larger quantity of rainfall was allowed, keeping in view the desire to select only such dry spells as fell very far short of the normal quantity of rain for the dry interval. In the course of 33 years there have been 58 periods answering the requirements of the definition, averaging a little less than two per year. A drought of this character cannot be regarded as severe, but it may be followed by considerable loss to the farmer or trucker

during certain critical periods. Ordinarily there are from ten to twelve days per month with rain to the extent of .01 inch, giving a ratio of one day with rain to two without. These are not uniformly distributed through the month, but are very likely to occur in groups of two or three days.

The total monthly frequency of periods of this class, together with the average, the maximum and the minimum number of days included, is shown in the following tabular statement:

DRY SPELLS IN 33 YEARS.
(With less than one-tenth of an inch of rainfall in two weeks or more.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Total frequency	2	3	3	3	7	3	3	3	6	12	5	8	58
Max. duration..	21	31	31	22	36	29	25	45	34	51	48	51	51 days
Min. " ..	16	18	19	14	14	20	22	22	17	15	14	20	14 "
Aver. " ..	18	22	26	19	21	25	23	30	25	27	32	29	25 "
Aver. rainfall..	.05	.17	.12	.15	.11	.21	.10	.28	.12	.20	.17	.30	.18 inch

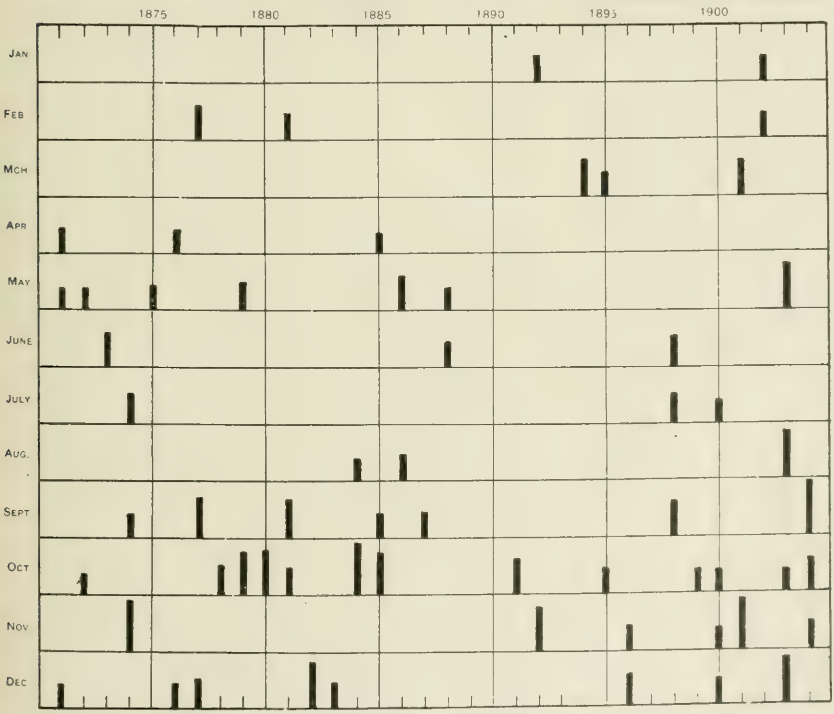


FIG. 59.—Dry Periods.

The diagram shows the frequency of occurrence and the seasonal distribution of all periods of two weeks or longer with a precipitation of one-tenth of an inch or less from 1871 to 1904. The length of the period is roughly shown by the length of the heavy vertical lines. The exact duration of the period is shown in Table LIII.

TABLE LIII.—DRY SPELLS.

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	No. of dry spells
				26	*31*							*16*	
1871				0.25	.08							.10	3
				22	**21**							**21**	
					17					*22*			
1872					.01					.10			2
					14					**15**			
						28							
1873						.29							1
						29							
							3		*14*		*17*		
1874							.13		.05		.22		3
							25		**20**		**48**		
					23								
1875					.03								1
					17								
				22								*17*	
1876				.02								.03	2
				19								**20**	
		22							*5*			*29*	
1877		.22							.17			.06	3
		31							**34**			**23**	
										6			
1878										.10			1
										23			
					15					*20*			
1879					.04					.30			2
					16					**36**			
										21			
1880										.59			1
										38			
		9							*9*	*8*			
1881		.23							.16	.05			3
		18							**33**	**19**			
												9	
1882												.66	1
												41	
												18	
1883												.31	1
												22	
								27		*21*			
1884								.06		.39			2
								22		**51**			
				30					*30*				
1885				.18					.17				2
				14					**19**				
					4			*29*		*25*			
1886					.23			.24		.27			3
					28			**22**		**36**			
									9				
1887									.04				1
									17				
					8	*22*							
1888					.05	.22							2
					15	**20**							
1889													0
1890													0

TABLE LIII CONT.—DRY SPELLS.

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	No. of dry spells
1891										*6* .10 **30**			1
1892											*2* .26 **38**		1
1893	*28* .04 **16**							*23* .55 **45**					2
1894			*20* .12 **31**										1
1895			*1* .16 **19**							*7* .14 **18**			2
1896											*3* .26 **22**	*29* .27 **29**	2
1897													0
1898						*10* .13 **25**	*18* .10 **23**		*21* .11 **27**				3
1899										*28* .13 **20**			1
1900							*18* .07 **22**			*30* .10 **16**	*23* .0 **14**	*27* .09 **23**	4
1901			*3* .09 **27**								*22* .13 **39**		2
1902	*20* .06 **21**	*20* .06 **18**											2
1903					*22* .36 **36**					*7* .10 **20**		*8* .89 **51**	3
No. of dry spells	2	3	3	3	7	3	3	3	6	12	5	8	58

Table LIII contains a list of all of the more pronounced dry periods occurring near Baltimore from 1871 to 1903. No strict definition of a dry spell has been adhered to in the selection of these periods, but the table contains all periods exceeding two weeks during which the precipitation amounted to less than one-tenth of an inch. The length of the dry spell in days is indicated by the figures in heavy face type, the date of ending by *italic* figures, and the total precipitation during the period by roman figures.

These dry spells are most frequent in the month of October, and hence after the harvest season. Their occurrence in May has been comparatively frequent. Coming at a time when soil moisture is a matter of the highest importance, the dry spells of this period are serious matters. The

seasonal distribution of these periods of deficient moisture is shown graphically in Fig. 59 for each year from 1871 to 1903.

In another classification of dry spells, all periods of ten or more consecutive days were included in which precipitation was less than .01

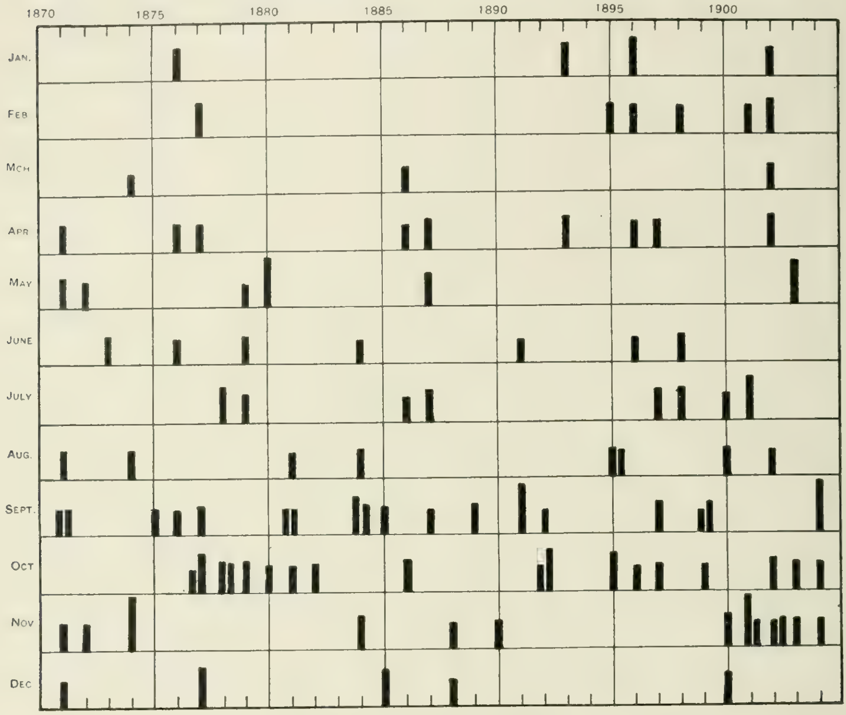


FIG. 60.—Dry Periods.

The diagram shows the frequency of occurrence and the seasonal distribution of periods with less than one-hundredth of an inch of precipitation in ten days or more from 1871 to 1904. The relative length of the period is approximately shown by the length of the heavy black vertical lines.

inch. The total number of such periods, with the average and greatest duration, is shown in the following figures:.

DRY SPELLS IN 33 YEARS.

(With less than one-hundredth of an inch of rain.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Total number	4	6	3	9	6	7	8	8	17	17	12	5	102
Average duration	14	12	11	12	14	11	12	11	12	13	14	14	12 days
Greatest duration	18	14	11	14	21	12	18	12	22	19	29	17	29 "

The above table reveals the interesting fact that the longest period experienced by Baltimoreans in 34 years without rain was 29 days. This occurred in November, 1874. September and October share the distinction of having 17 periods each of this class of dry spells out of a total in 34 years of 102. The average duration of such periods is only 12 days. These facts are not in accordance with popular impressions. Scarcely a summer passes without some reference to periods of five or six weeks "without a drop of rain." These statements, upon investigation, are generally reduced to "no rain of consequence." The dry spells of this class are graphically shown in Fig. 60. There seems to be no apparent periodic grouping of these periods of deficient rainfall, either in Fig. 59 or in Fig. 60. The following list comprises seasons with a marked deficiency in rainfall:

SEASONS WITH DEFICIENT PRECIPITATION.

(Departures below the normal in inches and hundredths.)

Winter.	Spring.	Summer.	Autumn.
1829-30....4.17	1822....5.11	1844....4.34	1819....4.57
1864-65....4.70	1827....4.12	1849....4.14	1825....4.79
1870-71....6.00	1845....4.46	1864....6.66	1842....4.22
1871-72....5.73	1847....6.03	1869....7.69	1863....4.32
1900-01....4.80	1855....5.91	1870....4.85	1870....4.33
	1856....4.87	1893....6.69	1879....5.06
	1866....5.85	1894....6.21	1884....5.23
	1869....4.49		1903....4.56
	1900....4.66		

Wet Spells.

While rain or snow storms do not usually exceed two or three days in duration, there are frequently periods of much more extended rainy or unsettled conditions. The more conspicuous "wet spells" occurring since 1871 are enumerated in Table LIV, which contains a list of all periods of 10 days or less during which the rainfall or snowfall was equal to or exceeded the *mean monthly amount*. Longer periods were included when the precipitation was proportionately excessive. The last day of the wet spell and the duration in days are indicated in the table, together with the total amount of the precipitation. Such periods have been recorded on an average of less than two times per year, or, more accurately, 51 times during 33 years; the limits of variability are 0 and 5. They occur in all months of the year, with a decided preponderance, however, in the

warm months of July, August and September. Their frequency of occurrence and seasonal distribution are shown graphically in Fig. 61.

One of the most remarkable periods of unsettled weather was that accompanying the northeast storm of April 19-25, 1901. Rain began early in the morning of the 19th and continued during the greater part of

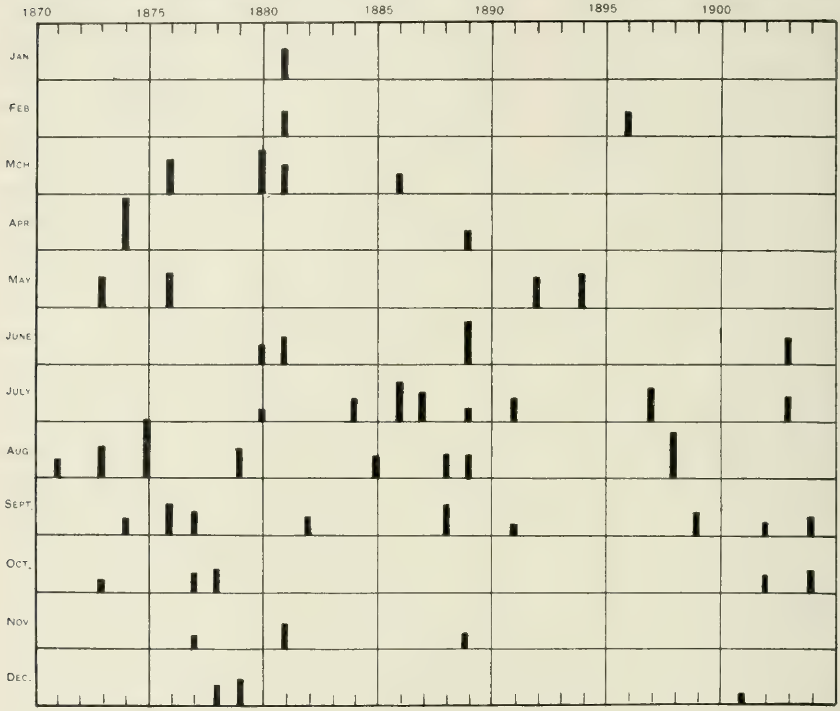


FIG. 61.—Wet Periods.

The diagram shows the frequency and seasonal distribution of periods of ten days or less in which the *average monthly amount* of precipitation was recorded. The amount recorded is roughly indicated by the length of the heavy vertical lines; the exact amounts and the length of the periods are shown in Table LIV.

seven days, or 162 hours between the beginning and ending of precipitation. The rainfall was not continuous, however, scattered showers falling on April 21, 22, 23 and 25. The total amount of rainfall recorded was 2.03 inches, not a large amount considering the great duration of the storm. Another noteworthy rainstorm was that of May 16-26, 1894. During this period of eleven days the rainfall was scattered and at times

heavy. The actual duration of precipitation was about 63 hours. The total amount recorded during the entire storm was 4.45 inches.

TABLE LIV.—WET SPELLS.

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	No. of wet spells.
1871	....	....	....	....	....	....	....	*1* 7 **4.33**	....	....	....	....	1
1872	....	....	....	....	....	....	....	....	....	....	....	....	0
1873	....	....	....	....	*11* 11 **3.94**	....	....	*23* 14 **8.81**	....	*21* 4 **3.72**	....	....	3
1874	....	....	....	*29* 23 **6.39**	....	....	....	....	*20* 6 **4.19**	....	....	....	2
1875	....	....	....	....	....	....	....	*24* 29 **9.61**	....	....	....	....	1
1876	....	....	*28* 13 **5.48**	....	*22* 14 **4.92**	....	....	....	*24* 18 **10.10**	....	....	....	3
1877	....	....	....	....	....	....	....	....	*15* 10 **5.23**	*10* 7 **4.43**	*26* 5 **3.79**	....	3
1878	....	....	....	....	....	....	....	....	....	*31* 10 **3.61**	....	*15* 7 **3.77**	2
1879	....	....	....	....	....	....	....	*26* 12 **5.76**	....	....	....	*26* 21 **5.17**	2
1880	....	....	*19* 17 **3.71**	....	....	*16* 7 **4.25**	*23* 4 **4.73**	....	....	....	....	....	3
1881	*14* 11 **3.46**	*19* 10 **4.61**	*13* 11 **5.65**	....	....	*11* 11 **4.07**	....	....	....	....	*4* 12 **4.09**	....	5
1882	....	....	....	....	....	....	....	....	*27* 7 **4.61**	....	....	....	1
1883	....	....	....	....	....	....	....	....	....	....	....	....	0
1884	....	....	....	....	....	....	*31* 9 **5.20**	....	....	....	....	....	1
1885	....	....	....	....	....	....	....	*8* 8 **5.60**	....	....	....	....	1
1886	....	....	*31* 6 **3.83**	....	....	....	*27* 15 **6.37**	....	....	....	....	....	2
1887	....	....	....	....	....	....	*27* 11 **6.98**	....	....	....	....	....	1
1888	....	....	....	....	....	....	....	*13* 9 **4.30**	*18* 12 **4.53**	....	....	....	2
1889	....	....	....	*30* 6 **6.21**	....	*4* 17 **7.63**	*4* 4 **4.70**	*2* 9 **5.52**	....	....	*13* 6 **3.39**	....	5
1890	....	....	....	....	....	....	....	....	....	....	....	....	0

TABLE LIV CONT.—WET SPELLS.

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	No. of wet spells
1891	....	....	....	....	....	....	*8* 8 **4.43**	....	*6* 2 **4.86**	....	....	....	2
1892	....	....	....	....	*21* 11 **4.81**	....	....	....	....	....	....	....	1
1893	....	....	....	....	....	....	....	....	....	....	....	....	0
1894	....	....	....	....	*28* 13 **4.55**	....	....	....	....	....	....	....	1
1895	....	....	....	....	....	....	....	....	....	....	....	....	0
1896	....	*9* 9 **5.13**	....	....	....	....	....	....	....	....	....	....	1
1897	....	....	....	....	....	....	*29* 13 **6.31**	....	....	....	....	....	1
1898	....	....	....	....	....	....	....	*13* 19 **7.15**	....	....	....	....	1
1899	....	....	....	....	....	....	....	....	*26* 8 **6.03**	....	....	....	1
1900	....	....	....	....	....	....	....	....	....	....	....	....	0
1901	....	....	....	....	....	....	....	....	....	....	....	*30* 5 **4.24**	1
1902	....	....	....	....	....	....	....	....	*26* 2 **5.29**	*5* 6 **4.11**	....	....	2
1903	....	....	....	....	....	*16* 11 **4.02**	*20* 10 **5.98**	....	....	....	....	....	2
No. of wet spells.	1	2	4	2	4	4	8	8	8	4	3	3	51

Table LIV contains a list of all of the more pronounced wet spells occuring near Baltimore from 1871 to 1903. The table includes all periods of 10 days or less during which the *average monthly* amount was recorded. Longer periods were included when the precipitation was proportionately excessive. The last day of the wet spell and the duration in days are indicated by figures in *Italics* and Roman respectively; the bold face type indicates the amount of precipitation recorded during the stated period, in inches and hundreths.

Table LIV comprises the more conspicuous wet spells of the past 34 years based upon excessive *amounts* of rain. Another table was prepared, but is not published in full, in which the basis of selection is the duration of unsettled, rainy weather. It includes periods of six or more

consecutive days with a "trace" or more of precipitation, 8 days with not more than one day without rain or snow, or 10 days with not more than two days without precipitation. More extended periods were included when precipitation occurred on two in each successive period of three days. The total number of "unsettled periods" of this description comprised within the 34 years is 164. The distribution throughout the year is indicated in the following summary; the last line indicates the number of intervening days without rain:

PERIODS OF UNSETTLED WEATHER.

(Six or more consecutive days with rain.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Total frequency	11	15	20	14	23	13	12	17	9	7	11	12	164
Maximum duration in days	19	17	22	13	23	18	15	19	12	10	10	22	23
Number of days without rain	4	4	2	1	4	3	2	4	0	0	1	6	4

SEASONS WITH EXCESSIVE PRECIPITATION.

(Departures above the normal, in inches and hundredths.)

Winter.	Spring.	Summer.	Autumn.
1823-24....5.95	1829.... 6.89	1817....12.25	1821....10.33
1839-40....4.90	1839.... 7.59	1820.... 4.55	1833.... 4.00
1858-59....9.95	1851.... 4.99	1829.... 6.87	1843.... 7.35
1865-66....4.80	1854.... 7.09	1836.... 8.00	1854.... 9.13
1880-81....5.44	1858.... 4.71	1837.... 4.05	1873.... 4.13
1881-82....5.04	1859.... 5.95	1838.... 5.45	1876.... 6.22
1883-84....4.51	1863.... 6.13	1846.... 5.62	1877.... 7.51
1901-02....4.83	1890....10.34	1856.... 5.02	1889.... 5.33
1902-03....4.93	1892.... 5.81	1857.... 4.10	1902.... 7.92
		1885.... 4.12	
		1889.... 5.96	
		1891.... 4.84	
		1903.... 5.90	

The Distribution of Precipitation in Normal, Dry and Wet Years.

The comparatively uniform distribution of precipitation throughout the year in the vicinity of Baltimore is well shown in Fig. 62 and Fig. 63. In Fig. 62 the total monthly amounts are shown for the dry year of 1900, when but 31.57 inches were recorded, 12 inches below the normal amount, and for the year 1889, which had an excess of nearly 19 inches. For purposes of comparison, a normal year is placed between the typical dry and wet years. In a similar manner the distribution of pre-

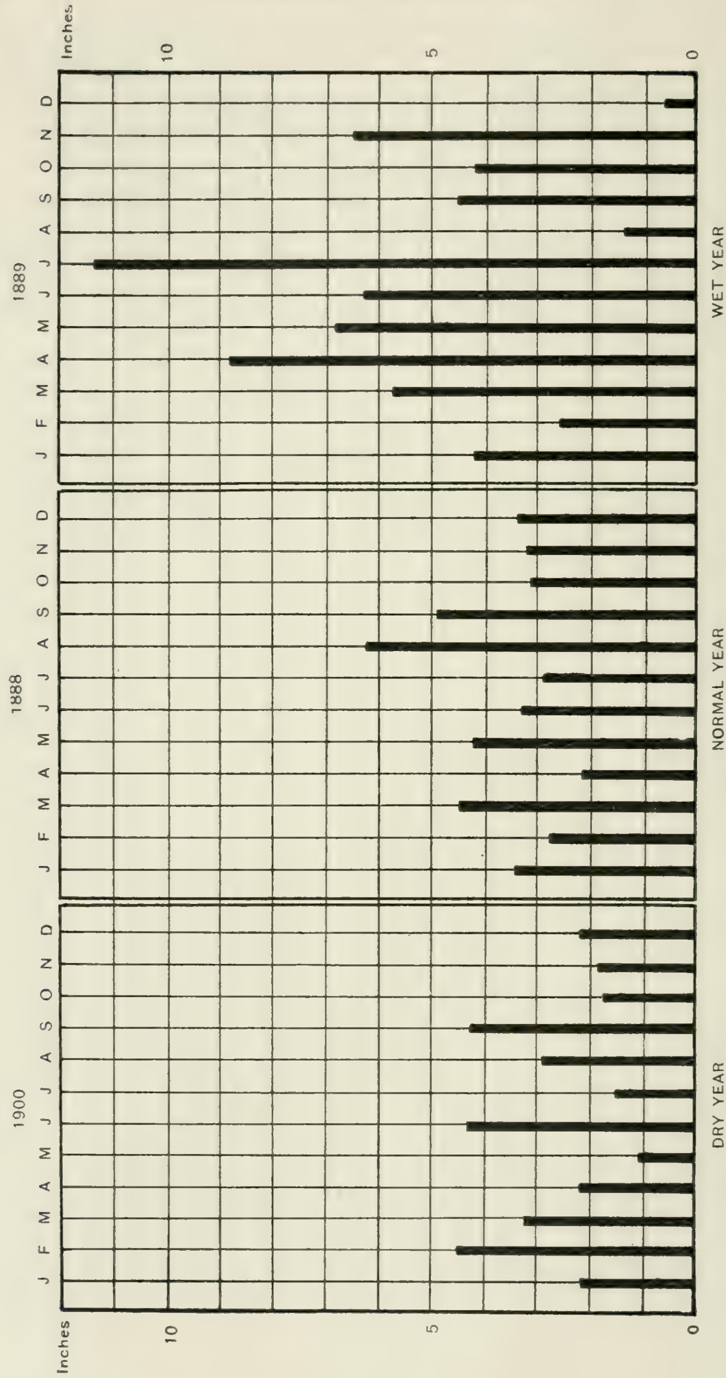


FIG. 62.—Total Monthly Precipitation During a Dry Year, a Normal Year and a Wet Year.

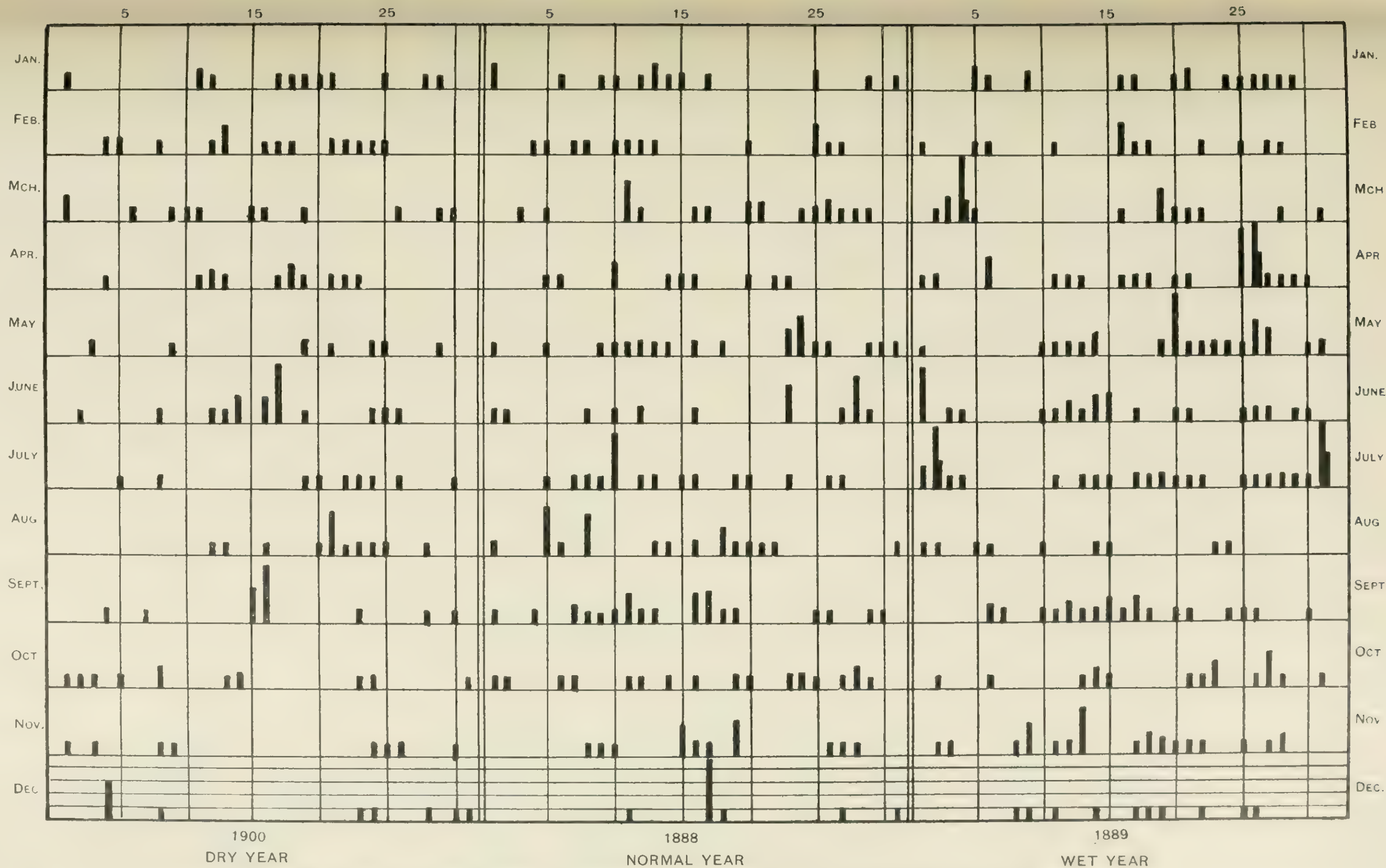


FIG. 63.—Daily Precipitation During a Dry Year, a Normal Year and a Wet Year.

The amount of precipitation is roughly indicated by the length of the heavy vertical lines; spaces between the horizontal lines in the division for December represent half an inch.

cipitation by days and months is shown for the same years in Fig. 63. The depth of rainfall is indicated by the length of the heavy vertical lines. The dry year (1900) was deficient in rainfall frequency as well as in amount. The normal year (1888) had 154 rainy days; the dry year (1900) had 115, and the wet year (1889) had 164. The rainfall of the dry year was only about half that of the wet year, the amounts being 31.57 inches and 62.35 inches, respectively. The normal precipitation is 43.34 inches. The great excess in the wet year was due to the heavy spring and early summer rains of 1889.

TABLE LV.—SUMMARY OF PRECIPITATION DATA.
(1871-1903.)

	Means.				Monthly and annual amounts.						No. of days* with precipitation.			Average* duration of rainfall 1893 to 1902.	Greatest in 24 hrs.	
			Mean depart.		Greatest.			Least.								
	Means	As per ct. of ann'l mean	Inches	per ct.	Depth	Year	Per ct. of Mean	Depth	Year	Per ct. of Mean	Average	Greatest	Least		Depth	Year
														h. m.		
January	3.20	7	1.11	35	6.42	1892	201	0.88	1872	28	12	19	4	7:18	1.95	1896
February...	3.70	8	1 47	40	7.07	1896	194	0.65	1901	18	11	19	4	8:14	3.48	1896
March.......	3.99	9	1.44	36	7.94	1891	199	1.19	1894	30	13	19	8	6:13	3.51	1881
April	3.27	8	1.19	36	8.70	1889	266	1.37	1885	42	11	16	4	6:25	3.58	1889
May.	3.63	8	1.61	44	7.26	1894	200	1.00	1900	28	12	21	5	4:23	2.99	1886
June	3.78	9	1.45	39	8.08	1883	215	0.90	1901	24	10	16	6	2:45	4.47	1885
July	4.66	11	2.03	44	11.03	1889	241	1.40	1881	31	12	18	7	3:03	4.02	1889
August	4.20	10	1.80	43	9.49	1873	229	0.64	1877	15	11	21	6	2:42	4.36	1873
September .	3.85	9	1.83	46	10.52	1876	267	0.09	1884	2	9	17	2	4:03	4.76	1895
October	2.99	7	1.48	50	6.85	1902	231	0.16	1874	5	9	16	2	5:30	3.42	1873
November..	2.99	7	1.12	37	6.85	1877	224	0.65	1882	21	10	16	4	6:15	2.85	1877
December ..	3.07	7	1.28	41	7.07	1901	228	0.37	1896	12	11	17	5	6:45	2.88	1901
Year	43.34	..	5.36	12	62.35	1889	144	31.57	1900	73	131	164 in 1889	104 in 1871	5:18	4.76	1895

* Omitting days with only a "trace" of rainfall or snowfall.

Table LV contains a summary of the principal facts relating to precipitation and published in full in preceding tables. The first column of figures shows the normal monthly precipitation based on 33 years' observations; the second column shows the proportion of the annual precipitation which falls in each month; the third column shows the average amount by which the actual monthly fall differs from the normal monthly fall, either above or below; the next following column of figures shows the same fact expressed as a percentage of the normal monthly precipitation.

Snowfall.

There are many difficulties in the way of securing accurate measurements of the amount of snowfall, difficulties which are inherent in the conditions attending precipitation in general, together with the additional one introduced when the temperature is at or near the freezing point of water. The method of exposure of the snow-gauge is of highest importance even under favorable atmospheric conditions for securing all the falling snow. When the wind is high, and especially when it blows in gusts, the snow is drifted and blown about to such an extent as to make it impossible to catch any but a small percentage of the total fall in the gauge. Under such circumstances it is necessary to resort to a different method of measurement. In an open and exposed area several measurements are made of the actual depth in inches of snow on the level ground at points which, in the estimation of the observer, represent most nearly the average depth in the vicinity of his station. The average of these measurements is then accepted as the true depth of snowfall. In order to secure the equivalent depth in melted snow, the several measured depths are melted and the average depth of water obtained is computed. The amount of water yielded by a given depth of snow varies greatly with the temperature of the snow and the conditions under which it falls. A light fluffy snow may require 15 to 20 inches for one inch of water; on the other hand, a wet soggy snow of 4 or 5 inches may melt to an inch of water. In rough measurements, under average conditions, the ratio is about ten to one, and this is the relation generally assumed. With a slight change in temperature at or near the freezing point, the snow melts as it falls, or after falling for some time it may change to rain. These are some of the difficulties encountered in an effort to secure reliable snowfall data.

The record of fairly accurate depths of snowfall at Baltimore begins with the year 1883. The record of frequency of snowfall begins much earlier, dating from the opening of the Weather Bureau Station in 1871. The actual monthly and seasonal amount of snowfall recorded during each month and year from 1883 to 1904 is shown in Table LVI, together with the monthly and seasonal average amounts for the entire period of 21 seasons. The seasonal variations are shown in Fig. 64. The average

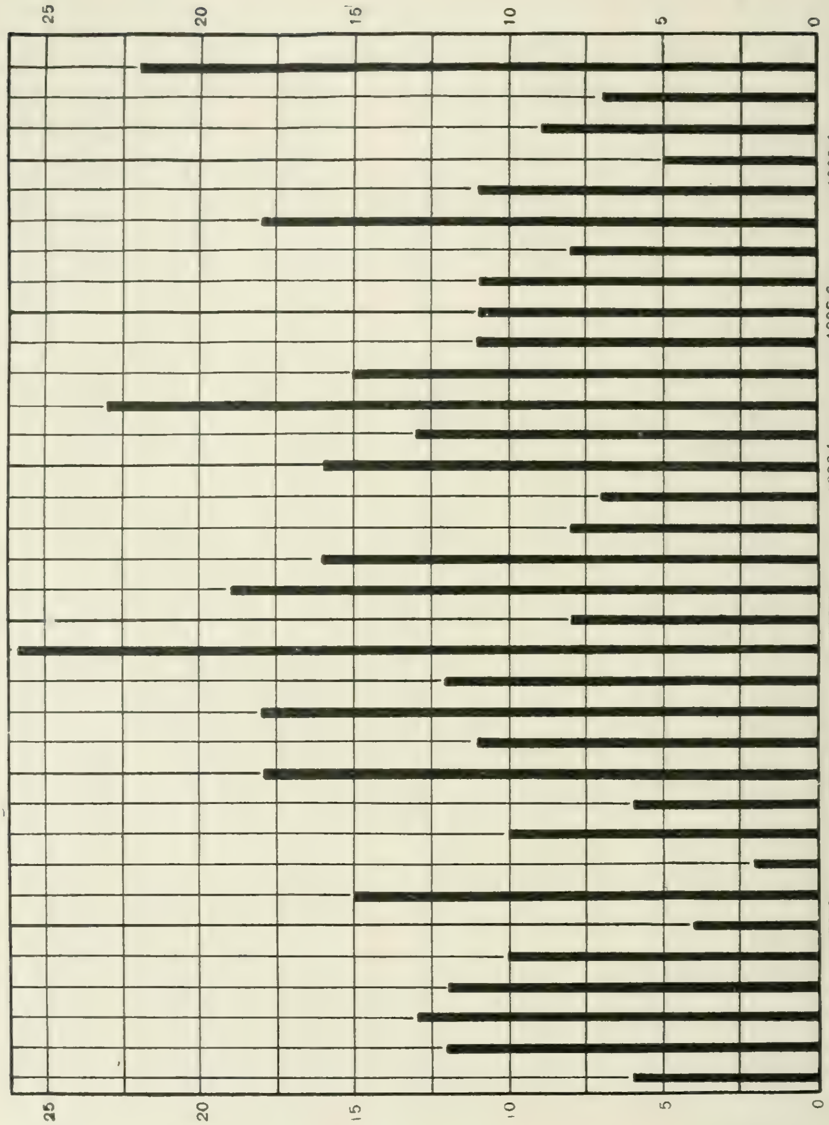


FIG. 64a.—Annual Frequency of Days with Snowfall to the Amount of One-tenth of an Inch.

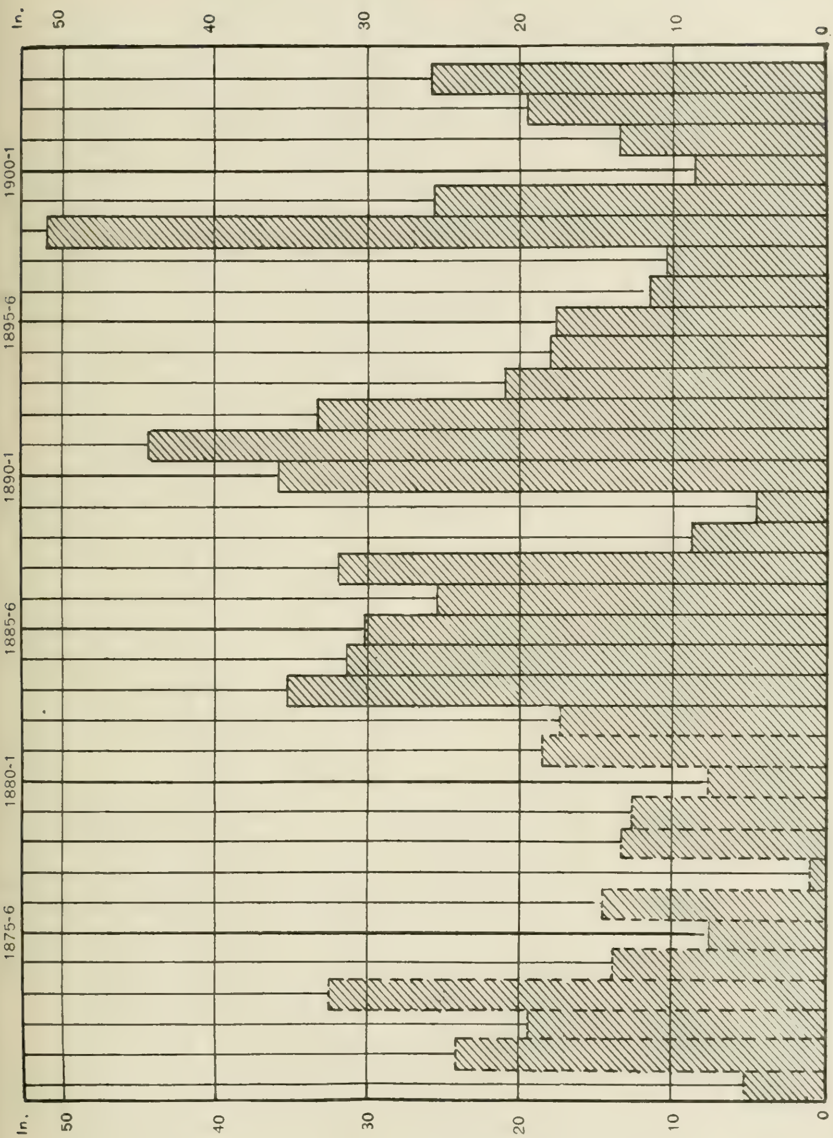


FIG. 64b.—Annual Depth of Snowfall in Inches.

TABLE LVI.—MONTHLY AND SEASONAL SNOWFALL.

(In inches and tenths.)

Season.	Oct.	Nov.	Dec.	Jan.	Feb.	Mch.	Apr.	May.	Season.
1883-4	0	0	4.4	14.2	0	8.7	8.0	0	35.3
1884-5	0	0.6	3.8	1.9	17.2	5.9	2.0	0	31.4
1885-6	0	0	0	13.0	15.3	2.0	0	0	30.3
1886-7	0	T	10.2	2.5	5.0	6.8	1.1	0	25.6
1887-8	0	0	12.0	8.8	3.9	7.4	0	0	32.1
1888-9	0	1.1	T	2.6	5.3	T	T	0	9.0
1889-90	T	0	0	0.1	2.5	2.3	T	0	4.9
1890-1	T	T	10.6	1.3	3.5	20.5	0	T	35.9
1891-2	0	T	T	14.5	4.2	25.6	T	0	44.3
1892-3	0	2.2	4.3	8.1	11.7	4.0	0	T	30.3
1893-4	0	0.2	3.1	1.0	11.7	T	5.0	0	21.0
1894-5	0	T	3.0	5.0	9.3	0.6	0	0	17.9
1895-6	T	T	0.2	1.0	2.8	13.8	T	0	17.8
1896-7	0	3.0	3.2	4.7	0.7	T	0	0	11.6
1897-8	0	T	2.6	5.4	0	2.4	0.1	0	10.5
1898-9	0	9.7	0.6	5.3	33.9	1.6	0	0	51.1
1899-1900	0	0	0.7	2.5	13.0	9.5	T	0	25.7
1900-1	0	T	T	6.5	2.1	0.1	0	0	8.7
1901-2	0	0.1	0.6	6.7	1.0	5.0	0	0	13.4
1902-3	0	0	7.0	6.8	6.0	0	0	0	19.8
1903-4	T	1.0	3.8	16.6	2.5	2.0	0	0	25.9
Average (1884-1904)	T	0.8	3.3	5.6	7.5	5.8	0.8	T	23.8
Greatest	T	9.7	12.0	16.6	33.9	25.6	8.0	T	51.1
Year	....	1898	1887	1904	1899	1892	1884	....	1898-9

depth of snow recorded during each month and the greatest and least monthly amounts recorded, are as follows:

MONTHLY SNOWFALL.

(In inches and tenths.)

(1884-1904)	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	Season
Average	*T	0.8	3.3	5.6	7.5	5.8	0.8	T	23.8
Greatest	T	9.7	12.0	16.6	33.9	25.6	8.0	T	51.1
Year	....	1898	1887	1904	1899	1892	1884	....	1898-9
Least	0	0	0	0.1	0	0	0	0	4.9
Year	....	....	....	1890	1898	1903	....	....	1889-90

* T represents a trace of snow.

February is the month of greatest snowfall, followed by March, with January third in the order of depth. The annual fall has varied from a minimum of about 5 inches in the season of 1889-90, to a maximum of 51 inches in 1898-9. Every month of the year excepting January has at some period since 1882 been entirely free from snow. The greatest monthly snowfall occurred during February, 1899, when about 34 inches

were recorded. Over half of this amount fell during the great blizzard of that month.

Expressed in terms of the percentage of the total annual precipitation, the average annual snowfall at Baltimore is 5.6 per cent; that is, about one-eighteenth of the amount representing the total annual precipitation falls in the form of snow. The percentage has varied from 1 per cent in the calendar year 1889, to 11 per cent in 1892. Computing the relative amounts which fall as snow and rain in the season of snowfall only, we have the following figures:

RAINFALL AND SNOWFALL OF THE WINTER SEASON.

(In percentage of total monthly precipitation.)

	Rainfall.	Snowfall.
November	97 per cent.	3 per cent.
December	89 " "	11 " "
January	83 " "	17 " "
February	82 " "	18 " "
March	86 " "	14 " "
April	98 " "	2 " "
Average	89 " "	11 " "

Even in the mid-winter months of January and February, the amount of snowfall is generally less than one-fifth the total precipitation for those months.

Dates of First and Last Snow.

The first snow of the season usually falls about the 15th of November, and the last about the first of April; hence the average length of the season of snowfall is about four months and a half. These first and last snows are, however, usually only light flurries. This is particularly true of the first autumn snows. In the 34 seasons since 1871, snow flurries have occurred as early as October 9, as in 1895 and 1903. The first snow of the season has occurred as late as December 17, as in 1883 and 1887. The early snows were not followed by either an abnormal amount or by an abnormal frequency of snows. The last snow of the season has occurred as late as May 6, as in 1891, and as early as February 22, as in 1903. Table LVII contains a record of first and last snows for each season from 1871 to 1904.

TABLE LVII.—DATES OF FIRST SNOW IN AUTUMN AND LAST IN SPRING.
(Including "traces" of Snow.)

Year.	First in Fall.	Last in Spring.	Year.
1871	Nov. 29	Mar. 4	1871
1872	" 29	" 22	1872
1873	" 13	" 21	1873
1874	" 13	Apr. 1	1874
1875	" 8	" 18	1875
1876	Oct. 15	Mar. 2	1876
1877	Nov. 10	" 29	1877
1878	Dec. 5	Feb. 25	1878
1879	Nov. 5	Apr. 5	1879
1880	" 13	Mar. 29	1880
1881	Nov. 24	Apr. 4	1881
1882	" 26	" 11	1882
1883	Dec. 17	Mar. 31	1883
1884	Nov. 3	Apr. 9	1884
1885	" 23	" 11	1885
1886	Nov. 13	Mar. 8	1886
1887	Dec. 17	Apr. 5	1887
1888	Nov. 24	Mar. 25	1888
1889	Oct. 23	Apr. 6	1889
1890	" 19	" 1	1890
1891	Nov. 28	May 6	1891
1892	" 9	Apr. 15	1892
1893	" 15	May 4	1893
1894	" 30	Apr. 12	1894
1895	Oct. 9	Mar. 20	1895
1896	Nov. 13	Apr. 7	1896
1897	" 23	Mar. 14	1897
1898	" 24	Apr. 28	1898
1899	Dec. 4	" 16	1899
1900	Nov. 9	" 4	1900
1901	Nov. 18	Mar. 6	1901
1902	Dec. 5	" 31	1902
1903	Oct. 9	Feb. 22	1903
1904	Nov. 13	Mar. 28	1904
Earliest	Oct. 9	Feb. 22	....
Latest	Dec. 17	May 6	....
Average	Nov. 15	Apr. 1	....

The Frequency of Days with Snowfall.

The frequency of days with snow, including "light flurries," varies greatly from year to year. The average number for a series of years is, however, fairly constant. Dividing the entire period of 30 years from 1871 to 1900 into three periods of ten years each, the average annual frequency was as follows:

AVERAGE ANNUAL SNOWFALL FREQUENCY.
(Including traces.)

1871 to 1880	16.4	days.
1881 to 1890	24.0	"
1891 to 1900	26.1	"
Mean (1891 to 1903)	22.0	"

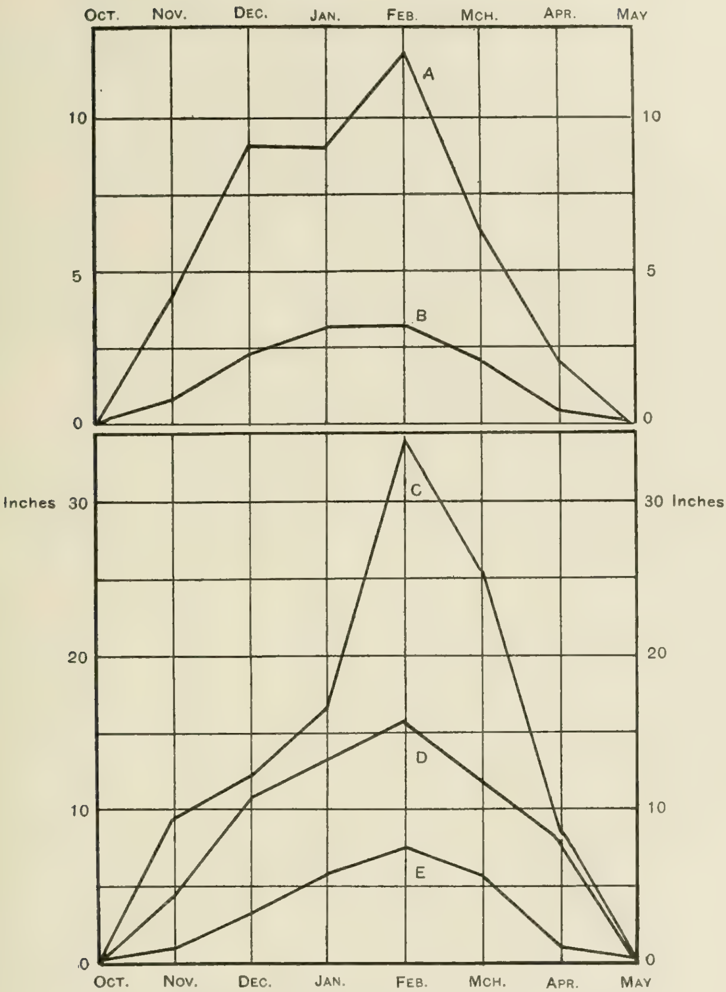


FIG. 65.—Monthly Frequency and Amount of Snowfall.

A. The greatest monthly frequency of days with appreciable snowfall.
B. The average frequency.
C. The greatest monthly amounts of snowfall.
D. The average monthly amounts of snowfall.
E. The least monthly amounts of snowfall.

With an average seasonal frequency of 22, the number has varied from 5 as in 1875-6 to 40 as in 1892-3. The average monthly and seasonal frequency for 34 seasons, including light flurries of snow, or

"traces," is indicated in the following table. The variations in the seasonal frequency are shown in Fig. 65.

FREQUENCY OF DAYS WITH SNOW.
(Including "snow flurries.")

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Season
Average	0.2	1.6	4.1	5.8	5.6	3.8	0.8	0.1	22 days
Greatest	2	5	10	13	14	8	3	1	40 "
Least	0	0	0	0	0	0	0	0	5 "

If we do not take into account days with light flurries of snow but only days during which a tenth of an inch or more fell, or days with

TABLE LVIII.—NUMBER OF DAYS WITH SNOWFALL EQUALLING OR EXCEEDING 0.10 INCH.

Season.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Season
1870-1	..	..	3	3	0	0	6
1871-2	0	0	5	2	5	0	12
1872-3	0	5	2	5	1	0	13
1873-4	0	4	2	5	0	1	12
1874-5	0	0	3	3	3	1	10
1875-6	0	0	0	2	2	0	4
1876-7	1	6	3	2	3	0	15
1877-8	0	0	1	1	0	0	2
1878-9	0	1	1	6	2	0	10
1879-80	0	2	0	2	2	0	6
1880-1	4	6	4	3	0	1	18
1881-2	0	2	4	2	2	1	11
1882-3	4	0	9	2	3	0	18
1883-4	0	3	3	0	5	1	12
1884-5	2	3	2	12	6	1	26
1885-6	0	0	4	3	1	0	8
1886-7	0	9	3	2	3	2	19
1887-8	0	3	6	3	4	0	16
1888-9	1	0	2	5	0	0	8
1889-90	0	0	1	3	2	1	7
1890-1	0	8	2	2	4	0	16
1891-2	0	0	4	3	6	0	13
1892-3	4	3	7	7	2	0	23
1893-4	1	2	2	8	0	2	15
1894-5	0	1	5	4	1	0	11
1895-6	0	1	1	3	6	0	11
1896-7	1	2	6	2	0	0	11
1897-8	0	3	3	0	1	1	8
1898-9	3	1	4	9	1	0	18
1899-1900	0	1	2	4	4	0	11
1900-1	0	0	2	2	1	0	5
1901-2	1	2	3	1	2	0	9
1902-3	0	2	3	2	0	0	7
1903-4	1	6	8	4	3	0	22
Average.							
1871-1880	0.1	2.0	2.0	3.1	1.8	0.2	9.3
1881-1890	1.1	2.6	3.8	3.5	2.6	0.7	14.3
1891-1900	0.9	2.2	3.6	4.2	2.5	0.3	13.7
1871-1903	0.7	2.2	3.1	3.4	2.2	0.4	12.0

what may be regarded as "appreciable" snowfall, the monthly and seasonal frequency is reduced considerably below the figures shown in the preceding paragraphs. A detailed list of such days is contained in Table LVIII, which gives a more satisfactory index of the snowfall condition of a season than the figures which include "traces." Basing our calculations upon "appreciable" snowfalls, we have an average seasonal frequency of 12 days. The season of 1877-8 contained but 2, while 26 were recorded in 1884-5. The variations in the seasonal frequency are shown in Fig. 65. The average per month for the 34 seasons since 1871 is as follows:

FREQUENCY OF DAYS WITH SNOW.

(Excluding traces.)

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Season
Average......	0.7	2.2	3.1	3.4	2.2	0.4	12.0 days
Greatest. ..	4	9	9	12	6	2	26 "
Least.........	0	0	0	0	0	0	2 "

Heavy Snowfalls.

The heaviest snow noted in the official records of the local office of the Weather Bureau fell during the great "blizzard" of February, 1899. The fall occurred in connection with an Atlantic coast storm which reached Maryland at a time when the Middle Atlantic states were in the embrace of the severest cold wave of the past 30 years. The ground was already covered by snow to the depth of about 10 inches, which fell from the 5th to the 8th, and to this layer 5 inches were added on the 12th and 15.5 inches on the 13th. At the close of the storm of the 12th and 13th, the depth of snow on the ground measured 30 inches in the city of Baltimore. Greater depths were reported from other parts of Maryland. The wind was high and the temperature was extremely low, ranging between 5° and 20° below zero within the state. As a result, the dry snow was very much drifted and settled in places to depths of 10 to 20 feet. The city was snowbound and all local traffic was blocked for two or three days.

The greatest depth of snowfall for any 24 consecutive hours during

this storm was 15.5 inches, according to the official measurements. Single snowfalls equalling or exceeding 10 inches in 24 hours are extremely rare in the vicinity of Baltimore. There was one on December 17, 1887, another on the 3d of February, 1886, and another on the 18th of March, 1892, in the 21 years since 1884. In Table LIX will be found a record of the heaviest 24-hour snowfall for each month and season from 1884 to 1904.

TABLE LIX.—GREATEST SNOWFALL IN 24 CONSECUTIVE HOURS.

Season.	Oct.		Nov.		Dec.		Jan.		Feb.		Mar.		April		May		Season.	
1883-4	..	..	..	..	2.9	23	3.0	15	0	0	5.0	5	8.0	9	..	..	8.0	Apr.
1884-5	..	..	0.5	30	1.0	18	1.0	28	5.5	25	1.5	13	2.0	11	..	..	5.5	Feb.
1885-6	..	..	T	25	0	0	6.5	9	13.0	3	2.0	8	..	..	..	..	13.0	Feb.
1886-7	..	..	T	13	3.1	5	1.5	5	4.0	26	3.5	4	0.7	2	..	..	4.0	Feb.
1887-8	..	..	..	..	10.6	17	3.2	9	1.8	12	3.5	5	..	..	..	..	10.6	Dec.
1888-9	..	..	1.1	26	T	19	2.5	20	2.3	27	T	7	T	6	..	..	2.5	Jan.
1889-90	T	23	0	0	0	0	0.1	23	1.5	2	3.4	31	2.0	1	..	..	3.4	Mar.
1890-1	T	19	T	27	7.0	26	1.0	25	3.0	26	9.5	27	..	..	T	6	9.5	Mar.
1891-2	..	..	T	29	T	17	7.0	15	4.0	5	12.0	18	T	15	..	..	12.0	Mar.
1892-3	..	..	1.2	9	4.0	20	4.8	12	7.8	17	3.5	4	..	..	T	4	7.8	Feb.
1893-4	..	..	0.2	15	3.0	5	0.5	27	3.5	25	T	26	4.0	10	..	..	4.0	Apr.
1894-5	..	..	T	30	3.0	26	2.6	29	4.3	7	0.6	11	..	..	..	..	4.3	Feb.
1895-6	T	9	T	20	0.2	12	1.0	19	1.0	4	6.0	11	T	7	..	..	6.0	Mar.
1896-7	..	..	3.0	30	2.3	22	2.6	27	0.5	8	T	14	..	..	..	..	3.0	Nov.
1897-8	..	..	T	23	2.0	26	3.0	31	T	25	2.4	2	0.1	28	..	..	3.0	Jan.
1898-9	..	..	4.5	26	0.6	12	2.8	1	15.5	13	1.6	7	T	16	..	..	15.5	Feb.
1899-1900	..	..	..	..	0.7	27	1.5	28	6.0	17	4.5	15	T	4	..	..	6.0	Feb.
1900-1	..	..	T	9	T	21	4.0	25	2.0	3	0.1	1	..	..	..	..	4.0	Jan.
1901-2	..	..	0.1	29	0.5	23	5.6	29	1.0	17	4.0	5	..	..	..	..	5.6	Jan.
1902-3	..	..	..	..	4.0	5	4.0	24	5.0	17	..	..	..	..	..	..	5.0	Feb.
1903-4	T	9	1.0	29	1.5	2	6.0	29	1.6	19	1.5	18	..	..	..	..	6.0	Jan.
Greatest	T	..	4.5	1898	10.6	1887	7.0	1892	15.5	1899	12.0	1892	8.0	1884	T	..	15.5	Feb.

The first column shows the amount of snowfall, and the second the date of occurrence.

Duration of Snowfall.

An effort has been made to obtain a value for the average duration of snowstorms in this vicinity. For this purpose the records were carefully examined for times of beginning and ending of snowfall for the period from 1884 to 1889, and the period from 1893 to 1902. No great accuracy can be claimed for the results, as there is no method in use for automatically recording beginnings and endings of snowfall. However, the figures given are based on a tabulation of 266 cases of snowfall during

TABLE LX.—SUMMARY OF SNOWFALL DATA.

	Means.		Greatest monthly am'ts.			Number of days with snow.						Greatest snowfall in 24 hours.	
			1883-1903.			1871-1903.						1883-1903.	
						Omitting traces.			Including traces.				
	Mean snowfall, 1883 to 1903.	As per cent. of annual precip.	Amount.	Year.	Per cent. of mean.	Average.	Greatest.	Least.	Average	Greatest.	Least.	Amount.	Year.
October	T	..	T	1895*	..	0	0	0	0.2	2	0	T	1895*
November	0.8	3	9.7	1898	1212	0.7	4	0	1.6	5	0	4.5	1898
December	3.3	14	12.0	1897	364	2.2	9	0	4.1	10	0	10.6	1887
January	5.6	24	14.5	1892	259	3.1	9	0	5.8	13	0	7.0	1892
February	7.5	32	33.9	1899	452	3.4	12	0	5.6	14	0	15.5	1899
March	5.8	24	25.6	1892	441	2.2	6	0	3.8	8	0	12.0	1892
April	0.8	3	8.0	1884	1000	0.4	2	0	0.8	3	0	8.0	1884
May	T	..	T	1893†	..	0	0	0	0.1	1	0	T	1893†
Season	23.8	..	51.1	1898-9	215	12	26 in 1884-5	2 in 1877-8	22	40 in 1892-3	5 in 1875-6	15.5	1899 in Feb.

T Indicates a "trace" of snow; an amount less than 0.1 inch.
* Also 1889 and 1890. † Also 1891.

16 years, and hence are fairly reliable. Traces of snow, or snow "flurries," were included in the calculations.

DURATION OF SNOWFALL.
(Including traces.)

	Nov.	Dec.	Jan.	Feb.	March	April	Season
Total number of snows	11	45	99	67	34	10	266
" duration in hours	60	239	428	395	169	47	1338
Average duration (in hrs. and min.)	5.30	5.20	4.20	5.50	5.00	4.45	5.00

Fogs.

Fogs in the vicinity of Baltimore are confined mostly to the fall, winter and early spring months. The record contained in Table LXI applies only to dense fogs surrounding the local station of the U. S. Weather Bureau office. Their frequency is doubtless greater as the harbor or the bay is approached. A fog has been regarded as dense when it obscured objects at a distance of about 1000 feet, and it has

been recorded only when it hung about the station for one hour or more. The table includes only such fogs as have been described and which occurred since 1891, the earlier records being regarded as less reliable.

TABLE LXI.—FREQUENCY OF DENSE FOGS.*

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l.
1891	3	1	1	..	..	..	..	..	..	..	2	6	13
1892	..	..	..	..	..	..	..	..	..	..	..	..	0
1893	1	..	..	1	..	..	..	..	..	1	1	5	9
1894	3	1	..	..	..	..	..	1	..	1	3	1	10
1895	1	..	1	..	..	..	..	..	2	3	5	3	15
1896	1	4	2	1	..	..	..	..	1	..	1	2	12
1897	1	1	2	1	..	..	..	..	..	..	2	1	8
1898	5	1	..	..	..	..	..	..	..	..	1	2	9
1899	2	2	3	..	..	..	..	..	..	5	..	1	13
1900	1	1	..	..	..	..	..	1	..	7	1	3	14
1901	..	..	1	..	1	1	..	..	..	2	3	5	13
1902	1	2	..	..	1	..	..	..	2	1	6	2	15
1903	4	4	8	1	..	..	..	..	..	..	2	..	19
Total (13 yrs.)	23	17	18	4	2	1	0	2	5	20	27	31	150
Aver. per year	1.8	1.3	1.0	0.3	0.2	0.1	0	0.2	0.4	1.6	2.1	2.4	11.5

* Fog about station for one hour or more, and too dense to see objects at 1000 feet.

During the 13 years from 1891 to 1903 there were 150 dense fogs recorded, or about 12 per year. The percentage of occurrence in the different months of the year is shown by the following figures:

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Percentage of total annual number	15	11	12	3	1	1	0	1	3	14	18	21	100

Arranging the months in the order of frequency of occurrence of fogs, we have: December, November, January, October, March, February, September, April, May and August, June, July. These fogs are not of long duration, rarely continuing any considerable portion of the day. When they do occur, however, they are a serious menace to the shipping interests in the harbor. A complete list of the dates of occurrence of all dense fogs about the local station of the U. S. Weather Bureau is given in Table LXII. The annual number since 1891 has varied from 19 in the year 1903 to none in the year 1892. None have been recorded in

TABLE LXII.—DATES OF OCCURRENCE OF DENSE FOGS.*

Year	Dates
1891	Jan. 1, " 2, " 11, Feb. 21, March 9, Nov. 21, " 22, Dec. 3, " 22, " 23, " 24, " 25, " 26
1892	0
1893	Jan. 1, April 29, Oct. 12, Nov. 2, Dec. 7, " 9, " 10, " 23, " 28
1894	Jan. 11, " 16, " 24, Feb. 9, Aug. 30, Oct. 20, Nov. 2, " 21, " 23, Dec. 12
1895	Jan. 21, March 7, Sept. 5, " 11, Oct. 2, " 7, " 26, Nov. 6, " 8, " 17, " 19, " 25, Dec. 18, " 19, " 28
1896	Jan. 29, Feb. 1, " 4, " 5, " 29, March 26, " 30, April 6, Nov. 26, Dec. 7, " 30
1897	Jan. 3, Feb. 6, March 19, " 21, April 5, Nov. 5, " 21, Dec. 9
1898	Jan. 6, " 11, " 12, " 13, " 20, Feb. 10, Nov. 5, Dec. 20, " 21
1899	Jan. 14, " 24, Feb. 18, " 21, March 4, " 5, " 18, Oct. 11, " 15, " 17, " 26, " 27, Dec. 1
1900	Jan. 19, Feb. 8, Aug. 30, Oct. 22, " 23, " 24, " 25, " 26, " 27, " 28, Nov. 25, Dec. 19, " 20, " 22
1901	March 25, May 24, June 14, Oct. 10, " 31, Nov. 1, " 16, " 22, Dec. 1, " 2, " 9, " 13, " 29
1902	Jan. 16, Feb. 27, " 28, May 19, Sept. 3, " 20, Oct. 19, Nov. 1, " 2, " 3, " 5, " 14, " 15, Dec. 3, " 16
1903	Jan. 1, " 27, " 28, " 29, Feb. 2, " 4, " 11, " 28, March 4, " 8, " 11, " 17, " 19, " 20, " 21, " 24, April 8, Nov. 10, " 23
1904	Jan. 22, Feb. 7, March 2, " 3, " 7, " 31, April 1, " 9, June 4, Sept. 14, Oct. 10, Nov. 3, " 4, " 24, Dec. 27

* Fog about station for one hour or more, and too dense to see objects at 1000 feet.

the month of July during this period of 13 years, and but one in the month of June, two each in May and August.

SUNSHINE AND CLOUDINESS.

Sunshine.

In connection with a discussion of the amount of sunshine recorded at Baltimore, it is important to know the method employed in obtaining the record. The instrument in use at the local office of the Weather Bureau since 1893 is of the kind known as the electrical thermometric recorder. The essential parts of the instrument are the two glass bulbs, one of which is covered with lamp-black. The two bulbs are joined by a tube, in the middle portion of which are the terminals of an electric circuit. The direct rays of the sun falling upon the black bulb

will raise the temperature of the air within to a higher degree than that within the bright bulb. This difference in temperature sends a column of mercury to the terminals in the connecting tube. When the sun passes behind a cloud or below the horizon, or, in other words, when the direct rays of the sun do not fall upon the bulb, the temperature in both is presumably the same, the mercury column remains below the terminals and the circuit remains open within the instrument. A recording device is placed in the electric circuit at some convenient point in the observing station. While the sun shines upon the black and bright bulbs, a characteristic line is drawn by a pen upon the revolving drum of the recording instrument. While the circuit is open a straight line is produced. The clock which forms part of the recording device closes the circuit every minute of the day and night. In this manner we obtain a record of sunshine or no sunshine once every minute between sunrise and sunset. At the close of the day we may then add up the number of minutes of sunshine. With these figures and knowing the exact number of hours and minutes between sunrise and sunset, we may obtain the percentage of possible sunshine for each day.

The hourly records for ten years show that there is a steady increase in the amount of sunshine in all months from sunrise to a maximum at about noon. The maximum hourly amount increases from 64 per cent in January to 81 per cent in September, and then again decreases to a minimum in January. The hourly distribution is shown in terms of percentages of the possible amount for each hour and month of the year in Table LXIII. The same distribution is graphically shown in Fig. 66, in which increase in the intensity of shading represents an increase in the amount of sunshine. In Fig. 67 the average increase from hour to hour for the entire year is indicated by means of a single curve; this shows a rapid and very uniform increase from sunrise to noon, and a similar decrease to sunset. This law of variation is common to all months of the year. The fact should not be overlooked that the amount of sunshine recorded as described above is not a complement of the amount of cloudiness. Sunshine may be, and frequently is, recorded when the sky is, to a great extent, clouded. The instrumental record only indicates

TABLE LXIII.—AVERAGE HOURLY DURATION OF SUNSHINE.

Hours.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l.
4- 5 a. m	.	..	..	..	29	40	44	..	..	..	..	..	9
5- 6 "	..	..	32	41	32	42	42	38	49	..	..	..	23
6- 7 "	..	33	31	44	38	49	48	41	48	38	28	..	33
7- 8 "	23	34	38	54	50	61	61	55	57	43	27	29	44
8- 9 "	34	46	51	64	58	70	68	66	67	53	40	38	55
9-10 "	49	59	62	68	65	75	77	73	74	64	52	54	64
10-11 "	56	68	67	72	71	78	80	79	80	69	61	61	70
11- Noon	63	74	70	72	72	77	79	80	81	70	64	65	72
Noon- 1 p. m	64	72	72	74	71	79	80	80	80	72	65	65	73
1- 2 "	62	71	70	72	70	78	80	77	77	72	64	62	71
2- 3 "	58	66	66	68	66	75	75	72	74	68	57	56	67
3- 4 "	50	61	63	62	56	70	67	66	70	60	43	41	59
4- 5 "	37	50	53	56	49	60	59	54	59	48	34	31	49
5- 6 "	36	42	39	43	34	46	47	38	47	47	..	..	35
6- 7 "	..	..	36	32	25	33	30	27	46	..	..	..	19
7- 8 "	..	..	..	..	18	31	27	30	..	..	..	..	9
Mean daily number of hours of sunshine	4.9	6.4	6.8	7.9	7.7	9.2	9.2	8.4	8.4	6.7	5.0	4.9	7.1
" " possible number	9.8	10.7	12.0	13.2	14.3	14.9	14.6	13.7	12.5	11.2	10.1	9.5	12.2
Percentage of possible number	50	59	57	60	54	62	63	61	67	60	50	51	58

Table LXIII shows the average duration of sunshine for each hour from sunrise to sunset, expressed in percentage of the possible amount of sunshine. The values are based on the continuous record of a self-registering thermometric sunshine recorder during the ten years from 1894 to 1903. The average daily duration is also given in hours and tenths and in percentage of the possible number of hours.

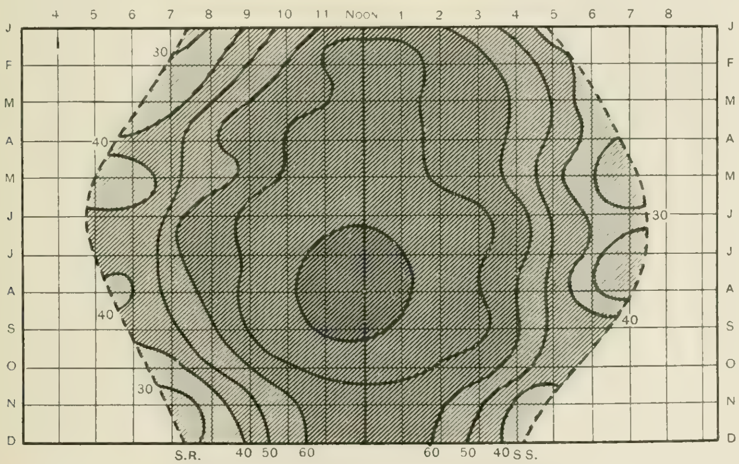


FIG. 66.—Mean Hourly Sunshine.

The diagram shows the mean hourly sunshine during each hour of the day and month of the year, expressed as a percentage of the highest possible amount for the season. It is based on the ten years' record of a self-registering thermometric sunshine recorder. The dotted lines S. R. and S. S. show the time of sunrise and sunset, respectively. The heaviest shading shows the time of occurrence of the highest percentage of sunshine. The curved lines mark intervals of 10 per cent in the amount of sunshine.

whether the face of the sun is or is not obscured at the moment of recording. It is only approximately an index of cloudiness.

There is, in all seasons of the year, an abundance of sunshine at this station. The amount varies considerably in different months, but in all months the average is above 50 per cent of the possible amount. January and December have the smallest amount in actual number of hours

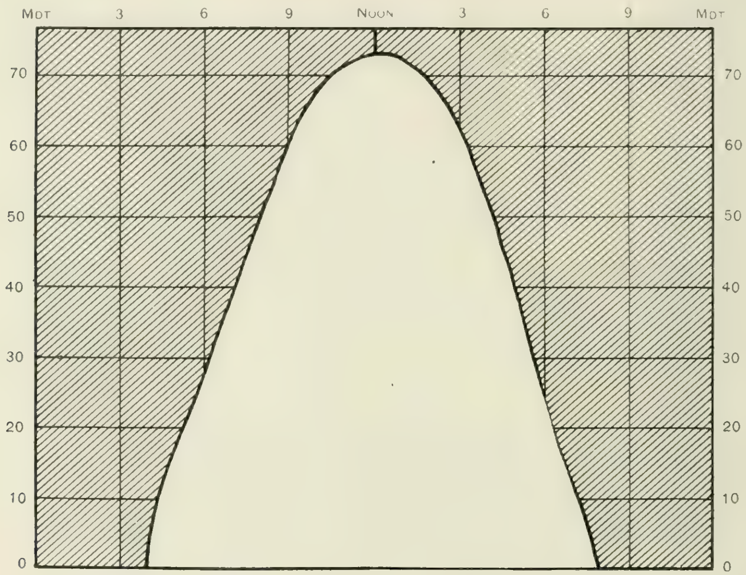


FIG. 67.—Mean Hourly Sunshine for the Year.

The diagram is based on the ten years' record of a self-registering thermometric sunshine recorder. The figures to the right and left of the diagram show the amount of sunshine, expressed as percentages of the highest possible amount.

as well as in percentage of the possible amount. The amount increases from 4.8 hours in December to a maximum of 9.2 hours in June, per day. September, with but 8.1 hours of sunshine, has a higher percentage than June, the value for the latter being 62 per cent, and the former 65 per cent.

The average monthly and annual amounts of sunshine are indicated by the following figures:

Average Daily Sunshine.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Average in hours..	4.9	6.4	6.8	7.9	7.7	9.2	9.1	8.6	8.1	6.8	5.5	4.8	7.2
" " percentage of possible amount......	50	59	57	60	54	62	62	63	65	60	51	50	58

The sunshine of any given month may vary greatly, however, from that indicated by the average figures given above. In the following table the months of the period from 1893 to 1903, during which the greatest and least amount of sunshine prevailed, are indicated, together with the monthly ranges. The years in which these amounts were recorded may be found by consulting Tables LXIV and LXV.

TABLE LXIV.—AVERAGE NUMBER OF HOURS OF SUNSHINE.
(By months and years.)

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l.
1893	....	....	....	....	....	....	9.7	9.0	6.5	7.0	5.8	....	....
1894	5.7	6.2	7.9	8.9	9.2	11.8	12.4	9.9	7.2	6.5	7.0	6.2	8.2
1895	5.2	8.4	8.4	9.0	7.7	9.0	10.1	11.0	9.7	8.0	4.5	3.4	8.0
1896	4.0	4.8	6.2	6.2	4.6	6.6	7.1	8.7	6.7	5.0	2.9	3.5	5.5
1897	3.7	4.3	6.0	7.1	8.2	7.3	6.0	6.6	9.2	5.8	5.6	5.1	6.2
1898	5.5	7.1	6.8	8.7	9.1	12.4	8.8	9.2	9.9	7.5	5.9	5.7	8.0
1899	6.4	7.3	8.8	11.0	5.8	9.5	10.3	7.3	9.5	7.0	10.0	4.8	8.1
1900	5.2	5.8	5.7	7.9	8.1	9.6	9.3	8.0	7.7	4.8	4.5	4.8	6.8
1901	4.4	7.0	6.1	5.5	5.4	10.0	8.0	8.4	7.9	8.7	4.9	4.8	6.8
1902	4.6	6.3	6.4	7.4	8.8	9.8	8.9	7.6	6.7	7.3	4.3	4.6	6.9
1903	4.6	6.3	5.9	7.4	9.7	6.1	10.8	6.9	9.1	6.1	5.5	5.7	7.0
Average	4.9	6.4	6.8	7.9	7.7	9.2	9.1	8.6	8.1	6.8	5.5	4.8	7.2

TABLE LXV.—PERCENTAGE OF POSSIBLE SUNSHINE.
(By months and years.)

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l.
1893	....	....	....	....	....	....	67	65	52	62	58	....	....
1894	59	58	66	67	64	80	85	72	57	58	70	66	67
1895	54	79	70	68	54	60	69	81	78	72	45	36	64
1896	40	45	52	47	32	45	48	64	54	44	29	37	45
1897	38	40	50	54	58	49	41	49	74	52	55	54	51
1898	56	66	57	66	64	84	60	67	80	67	59	60	66
1899	64	68	74	84	41	64	71	53	76	62	54	51	64
1900	53	54	48	59	57	65	63	59	62	43	45	50	55
1901	45	65	51	41	38	68	55	62	63	78	49	51	56
1902	47	58	54	56	61	66	61	55	54	65	43	49	56
1903	47	58	49	56	68	41	74	51	73	55	55	60	57
Average	50	59	57	60	54	62	62	63	65	60	51	50	58

HIGHEST AND LOWEST MEAN MONTHLY SUNSHINE.
(In percentage of the possible amount.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Highest mean..	64	79	74	84	68	84	85	81	80	78	70	66	67
Lowest mean..	38	40	48	41	32	41	41	49	52	43	29	36	45
Range..........	26	39	26	43	36	43	44	32	28	35	41	30	22

The months of least sunshine show an average of over 40 per cent, only the winter months and the month of May having at any time during the eleven years fallen below this value. The monthly range varies from 26 per cent in January and March to 44 per cent in the month of July. The average for the entire year has varied from 67 per cent in 1894 to 45 per cent in 1896, a range of 22 per cent.

TABLE LXVI.—SUNSHINE PHASES.
(Local time).

	Sunrise, 15th.	1st Mean.		Maximum.		2d Mean.		Sunset, 15th.
		Time. Hours ending a. m.	Value %	Time. Hours ending p. m.	Value %	Time. Hours ending p. m.	Value in hours	
January	7.17	10.10	50	1.00	64	4.00	4.9	5.02
February....................	6.52	10.00	59	12.20	74	4.10	6.4	5.37
March	6.11	9.30	57	1.10	72	4.30	6.8	6.07
April.	5.25	8.40	60	12.30	74	4.20	7.9	6.37
May..........................	4.47	8.30	54	12.50	72	4.20	7.7	7.05
June	4.33	8.10	62	1.10	79	4.50	9.2	7.26
July	4.45	8.20	63	12.20	80	4.30	9.2	7.25
August......................	5.13	8.30	61	12.20	80	4.30	8.4	6.55
September..................	5.41	9.00	67	12.20	81	4.20	8.4	6.09
October.	6.10	9.40	60	12.50	72	4.00	6.7	5.22
November.	6.43	10.00	50	1.00	65	3.30	5.0	4.46
December	7.12	9.50	51	1.10	65	3.20	4.9	4.39
Year	5.54	9.15	58	12.45	73	4.10	7.1	6.06

Table LXVI shows the time of day when the maximum amount of cloudiness is most likely to occur, and the time which most nearly represents the time of occurrence of the average daily cloudiness in the morning and afternoon.

Sunshine Phases.

Table LXVI indicates the hour of day during which the maximum amount of sunshine has occurred most frequently in the past eleven years; also the hours of the morning and afternoon during which the sunshine is most likely to be equivalent to the average amount for the day. These facts are of importance in selecting the best hours for observing and recording sunshine.

CLOUDINESS.

Recording the amount of cloudiness has always been an important feature of a regular observation in the work of the U. S. Weather Bureau. A careful record of the extent of cloudiness has been maintained at the local station of the Bureau since the establishment of the Service in January, 1871. At the present time, two direct observations per day are made, one at 8 a. m. and the other at 8 p. m. At various times since 1871 the following constituted the regular hours of observation:

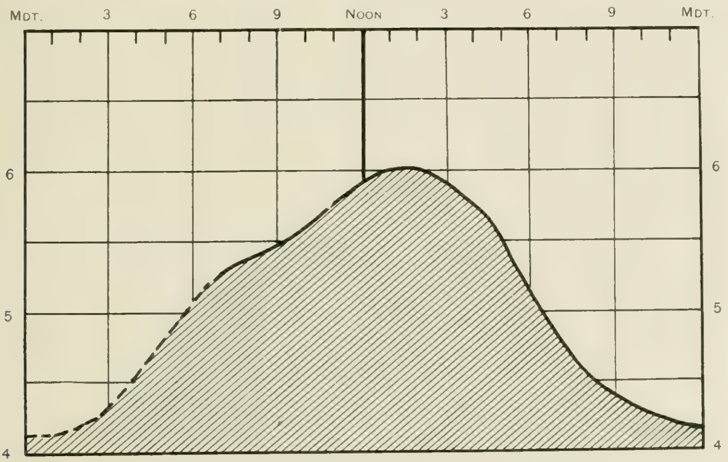


FIG. 68.—Average Hourly Cloudiness.

The diagram is based on a record of five years of direct observations at 12 stated hours of the day from 7 a. m. to 11.30 p. m. The cloudiness is rated on a scale from 0 to 10, the former figure representing a clear sky and the latter an overcast sky. The dotted line is based on interpolated values from midnight to 7 a. m., no direct observations being available for the period.

7 a. m., 8 a. m., 11 a. m., noon, 2 p. m., 3 p. m., 4.30 p. m., 7 p. m., 8 p. m., 9 p. m., 10 p. m. and 11 p. m. The amount of cloudiness is noted in terms of the number of tenths of the sky covered at the time of observation. In order to arrive at the law of increase and decrease in the diurnal amount of cloudiness, the average extent of cloudiness was determined for a period of five years at each of the 12 hours of observation mentioned above. These twelve periods of the day afford ample material for accurately noting the daily march of cloudiness between the hours of 7 a. m. and 11 p. m., but leave a serious gap

between midnight and early morning which could only be bridged over by interpolating the most probable values.

The following figures show the average values for the extent of cloudiness at the stated hours of the day:

AVERAGE CLOUDINESS.
(On a scale of one to ten.)

Hours of Observation.	For the Year.
7.00 a. m.	5.3 tenths of sky covered.
8.00 a. m.	5.1 " " " "
11.00 a. m.	5.7 " " " "
Noon	5.9 " " " "
2.00 p. m.	6.0 " " " "
3.00 p. m.	5.8 " " " "
4.30 p. m.	5.8 " " " "
7.00 p. m.	4.8 " " " "
8.00 p. m.	4.4 " " " "
9.00 p. m.	4.4 " " " "
10.00 p. m.	4.3 " " " "
11.00 p. m.	4.2 " " " "

These annual average values have been graphically presented in Fig. 68. The dotted contour line from midnight to 7 a. m. indicates that the curve is based on interpolated values. The form of the curve shows a steady increase in cloudiness from early morning to a maximum at 2 p. m., and then a somewhat more rapid decrease to midnight, with a probable minimum sometime in the early morning hours. The average daily cloudiness based upon the 8 a. m. and 8 p. m. observations is somewhat too low. Any of the series of three daily observations employed in past years by the U. S. Weather Bureau, the Smithsonian Institution or the Army Medical Department, will yield a daily average very closely agreeing with the daily mean based on the twelve daily observations distributed as noted in the preceding paragraph.

Clear, Partly Cloudy and Cloudy Days.

It has been the custom for many years to designate the character of the day as clear, partly cloudy or fair, and cloudy, the classification being based upon the average amount of cloudiness at two or more stated hours of the day, or upon prevailing conditions for the day. The sky is designated as *clear* when it is entirely free from clouds, or when less than one-third is covered by clouds; it is regarded as *fair* or *partly*

cloudy when covered to the extent of four to seven tenths; and *cloudy* when it is from eight to ten tenths overcast. There is no instrumental method for measuring the exact amount of cloudiness; hence the classification must be left to the judgment of the individual observer. However, it is a convenient method of designating the character of the day as regards the extent of sky covered by clouds and is a fair index of the amount of sunshine received at the observing station. The frequency

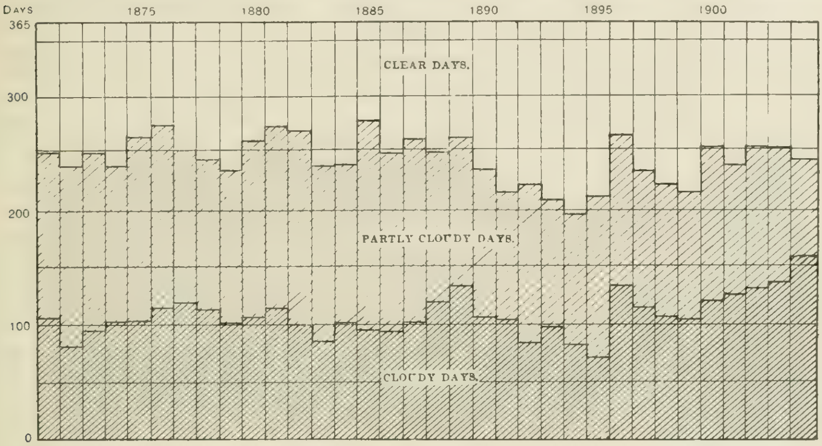


FIG. 69.—Relative Frequency of Clear, Partly Cloudy and Cloudy Days.

of occurrence of days of each of the classes at a given locality is a matter of the highest importance to health and personal comfort, and a vital factor in plant growth.

All days since 1871 have been grouped into the three classes described above. The variation in the frequency of occurrence of clear, partly cloudy and cloudy days from month to month and from year to year is shown in Tables LXVII, LXVIII and LXIX, and in Fig. 69. The mean monthly frequency of each class is shown in the following table:

MEAN MONTHLY CLOUDINESS.
(1871-1902.)

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Clear days......	8.3	8.4	8.8	9.2	9.5	9.0	10.0	10.7	11.9	12.4	10.2	9.7	118.1
Partly cloudy days......	12.1	10.9	11.5	11.8	11.6	14.0	13.3	12.9	10.5	10.2	10.2	11.5	140.5
Cloudy days....	10.6	8.9	10.7	9.1	9.9	7.3	7.4	7.4	7.5	8.7	9.6	9.4	106.6

Frequency of Clear Days.

The variation in the number of clear days from month to month and year to year is shown in Table LXVII. Variations in the annual fre-

TABLE LXVII.—NUMBER OF CLEAR DAYS.
(Less than 4 tenths of sky covered.)

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
1871	5	6	9	8	10	11	9	7	14	13	8	10	110
1872	10	4	11	13	15	6	9	13	13	9	12	8	123
1873	8	9	14	7	8	10	10	10	8	14	7	7	112
1874	7	9	9	5	13	4	11	14	13	10	14	6	115
1875	7	11	6	7	11	7	5	2	13	13	11	6	99
1876	10	9	8	6	8	5	4	8	6	9	2	11	86
1877	9	8	8	8	10	4	12	11	8	13	11	11	113
1878	11	8	10	6	11	7	16	9	10	10	12	8	118
1879	6	7	8	8	10	17	10	14	13	14	10	5	122
1880	6	8	8	11	15	8	2	5	12	13	7	6	101
1881	4	7	4	6	11	2	9	11	8	8	11	7	88
1882	5	9	8	7	6	4	6	9	10	12	9	8	93
1883	4	8	12	6	12	8	17	18	8	7	14	11	125
1884	8	3	6	7	9	13	8	9	19	16	15	10	123
1885	10	7	5	11	4	10	6	7	10	7	3	4	84
1886	6	8	8	9	8	6	13	12	6	16	10	9	111
1887	8	5	4	10	11	10	11	7	8	9	13	8	104
1888	5	10	11	12	3	14	13	12	7	8	8	11	114
1889	11	8	7	4	8	4	7	12	9	9	7	14	100
1890	7	9	8	16	7	12	13	9	8	10	15	13	127
1891	15	8	11	15	13	16	7	4	17	14	12	15	147
1892	10	7	13	11	9	8	16	11	19	17	9	13	143
1893	13	9	11	9	14	9	13	19	12	18	15	13	155
1894	12	9	13	11	12	17	19	19	11	15	16	12	166
1895	8	11	11	10	8	13	14	12	21	23	12	11	154
1896	9	6	12	9	5	6	4	15	10	12	5	4	97
1897	10	7	9	12	12	7	6	11	22	11	11	8	126
1898	6	15	7	7	5	11	14	13	20	15	12	16	141
1899	15	12	7	17	12	13	9	8	17	11	11	15	147
1900	5	7	4	13	9	7	15	13	11	9	6	8	107
1901	7	12	11	8	6	13	6	8	9	20	10	12	122
1902	9	12	10	5	9	5	6	9	10	13	8	11	107
1903	10	10	11	13	12	3	13	4	13	9	7	8	113
Average.													
1871-1880	7.9	7.9	9.1	7.9	11.1	7.9	8.8	9.3	11.0	11.8	9.4	7.8	109.9
1881-1890	6.8	7.4	7.3	8.8	7.9	8.3	10.3	10.6	9.3	10.2	10.5	9.5	106.9
1891-1900	10.3	9.1	9.8	11.4	9.9	10.7	11.7	12.5	16.0	14.5	10.9	11.5	138.3
1871-1902	8.3	8.4	8.8	9.2	9.5	9.0	10.0	10.7	11.9	12.4	10.2	9.7	118.1

quency are also graphically shown in Fig. 69 in connection with the partly cloudy and cloudy days. During the course of a year we may count on about 118 clear days, or days with a cloud covering of three-tenths or less. The annual frequency has varied greatly from 1871 to 1903. In 1885 but 84 were recorded, while in 1894 there were 166, or about double the number. The table shows a rather remarkable increase

in the ten-year average for 1891 to 1900 (138) over that of the decades from 1871-1880 (110) and 1881-1890 (107), a variation which is difficult to account for, considering the close approximation of the values for the two preceding ten-year periods.

TABLE LXVIII.—NUMBER OF PARTLY CLOUDY DAYS.

(From 4 to 7 tenths of sky covered.)

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
1871	13	16	12	16	13	13	15	12	10	8	7	13	148
1872	18	18	9	11	11	15	11	14	10	16	12	15	160
1873	14	13	9	12	12	12	15	9	14	12	19	16	157
1874	14	9	15	9	8	21	10	11	8	15	10	13	143
1875	11	14	14	14	15	15	16	12	13	9	9	20	162
1876	16	9	13	14	13	16	21	15	9	13	15	10	164
1877	11	13	8	9	15	15	9	10	10	10	11	9	130
1878	10	8	12	13	8	15	10	12	10	15	7	11	131
1879	15	7	15	10	14	8	15	10	13	11	16	8	142
1880	13	16	7	13	11	17	18	10	10	10	8	15	148
1881	11	13	13	14	12	14	17	17	14	16	8	15	164
1882	14	12	12	13	10	25	20	14	12	8	14	18	172
1883	11	15	11	16	13	17	11	9	13	15	8	15	154
1884	13	14	13	14	15	10	13	16	11	7	6	8	140
1885	12	15	18	11	10	15	20	16	16	16	14	19	182
1886	14	16	14	13	10	16	9	13	19	10	12	11	157
1887	16	11	14	13	14	13	11	16	15	12	13	12	160
1888	14	7	10	16	12	11	11	12	8	11	6	13	131
1889	8	8	14	17	15	14	10	13	8	9	8	6	130
1890	11	7	13	8	13	14	10	15	14	9	9	8	131
1891	8	10	5	9	5	6	14	16	11	8	12	8	112
1892	10	10	7	8	16	19	12	16	6	14	14	8	140
1893	10	10	11	11	8	11	14	6	9	4	6	12	112
1894	13	11	11	11	8	11	9	9	7	7	8	13	118
1895	15	15	15	12	19	11	9	17	8	6	8	6	141
1896	10	12	7	12	12	11	14	11	10	9	14	14	136
1897	8	5	10	11	8	16	15	13	6	8	9	13	122
1898	14	5	10	14	13	17	10	12	4	6	6	5	116
1899	5	5	10	8	9	11	16	13	8	9	8	9	111
1900	15	10	12	7	10	13	13	13	10	8	14	12	137
1901	12	12	11	4	9	11	15	14	12	5	8	6	119
1902	8	4	11	13	9	15	13	17	9	10	9	8	126
1903	10	6	7	3	9	11	12	11	10	7	15	13	114
Average.													
1871-1880	13.5	12.3	11.4	12.1	12.0	14.7	14.0	11.5	10.7	11.9	11.4	13.0	148.5
1881-1890	12.4	11.8	13.3	13.5	12.4	14.9	13.2	14.1	13.0	11.3	9.8	12.5	152.2
1891-1900	10.8	9.3	9.8	10.3	10.8	12.6	12.6	12.6	7.9	7.9	9.9	10.0	124.5
1871-1902	12.1	10.9	11.5	11.8	11.6	14.0	13.3	12.9	10.5	10.2	10.2	11.5	140.5

September and October have the highest percentage of clear days, followed closely by August, November and July. The minimum frequency occurs in January. There is an almost uniform increase in the number from January to a maximum in October, followed by a steady decrease to a minimum in January. The only interruption in the

regularity of the increase is a slight falling off in frequency in the month of June. In the months of September and October the number of clear days has occasionally reached 20 out of the total of 30 or 31 days; the number sometimes falls as low as 6 or 7; the average frequency for September is 11.9, and for October 12.4.

TABLE LXIX.—NUMBER OF CLOUDY DAYS.

(Over 7 tenths of sky covered.)

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
1871	13	6	10	6	8	6	7	12	6	10	15	8	107
1872	3	7	11	6	5	9	11	4	7	6	6	8	83
1873	9	6	8	11	11	8	6	12	8	5	4	8	96
1874	10	10	7	16	10	5	10	6	9	6	6	12	107
1875	13	3	11	9	5	8	10	17	4	9	10	5	104
1876	5	11	10	10	10	9	6	8	15	9	13	10	116
1877	11	7	15	13	6	11	10	10	12	8	8	11	122
1878	10	12	9	11	12	8	5	10	10	6	11	12	116
1879	10	14	8	12	7	5	6	7	4	6	4	18	101
1880	12	5	16	6	5	5	11	16	8	8	15	10	107
1881	16	8	14	10	8	14	5	3	8	7	11	9	113
1882	12	7	11	10	15	1	5	8	8	11	7	5	100
1883	16	5	8	8	6	5	3	4	9	9	8	5	86
1884	10	12	12	9	7	7	10	6	0	8	9	13	103
1885	9	6	8	8	17	5	5	8	4	8	13	8	99
1886	11	4	9	8	13	8	9	6	5	5	8	11	97
1887	7	12	13	7	6	7	9	8	7	10	4	11	101
1888	12	12	10	2	16	5	7	7	15	12	16	7	121
1889	12	12	10	9	8	12	14	6	13	13	15	11	135
1890	13	12	10	6	11	4	8	7	8	12	6	10	107
1891	8	10	15	6	13	8	10	11	2	9	6	8	106
1892	11	12	11	11	6	3	3	4	5	0	7	10	83
1893	8	9	9	10	9	10	4	6	9	9	9	6	98
1894	6	8	7	8	11	2	3	3	12	9	6	6	81
1895	8	2	5	8	4	6	8	2	1	2	10	14	70
1896	12	11	12	9	14	13	13	5	10	10	11	13	133
1897	13	16	12	7	11	7	10	7	2	12	10	10	117
1898	11	8	14	9	13	2	7	6	6	10	12	10	108
1899	11	11	14	5	10	6	6	10	5	11	11	7	107
1900	11	11	15	10	12	10	3	5	9	14	10	11	121
1901	12	4	9	18	16	6	10	9	9	6	12	13	124
1902	14	12	10	12	13	10	12	5	11	8	13	12	132
1903	11	12	13	14	10	16	6	16	7	15	8	10	138
Average.													
1871–1880	9.6	8.1	10.5	10.0	7.9	7.4	8.2	10.2	8.3	7.3	9.2	10.2	106.9
1881–1890	11.8	9.0	10.5	7.7	10.7	6.8	7.5	6.3	7.7	10.5	9.7	8.0	106.1
1891–1900	9.9	9.8	11.4	8.3	10.3	7.7	5.7	5.9	6.1	8.6	9.2	9.5	102.4
1871–1902	10.6	8.9	10.7	9.1	9.9	7.3	7.4	7.4	7.5	8.7	9.6	9.4	106.6

Frequency of Partly Cloudy Days.

The details concerning the monthly and annual distribution of partly cloudy days may be learned by consulting Table LXVIII. The average annual frequency is 140 days, with a maximum occurrence of 182 in

1885 and a minimum of 111 in 1899. The partly cloudy days are most frequent in June and least frequent in October and November. There is a fairly uniform distribution throughout the year, the monthly averages varying only between a minimum of 10.2 and a maximum of 14.0, as shown in Table LXVIII. The annual variations are shown graphically in Fig. 69.

Cloudy Days.

The frequency of occurrence of cloudy days during each month and year since 1871 is shown in Table LXIX. The average annual number for the entire period of 33 years has been about 107, with a maximum frequency of 138 in 1903 and a minimum of 70 in 1895. Cloudy days have been most frequent in the months of March (10.7) and January (10.6) and least frequent in the month of June (7.3). The average annual variation is shown graphically in Fig. 69.

THE WINDS.

INTRODUCTION.

A Robinson anemometer with a continuous recording attachment has been in operation since the establishment of the office of the U. S. Weather Bureau in January, 1871. Hence we have an excellent and complete record of the hourly changes in the velocity of the wind for a period of 34 years. While it is a matter of great importance to have a permanent observatory for meteorological observations, it is a difficult problem for the National Weather Service to secure such permanence in large and rapidly growing cities where changes in neighboring buildings so alter the conditions of exposure of instruments as to make a change in the location of the observatory a necessity. Since 1871 the successive changes in the elevation of the anemometer were as follows:

CHANGES IN THE ELEVATION OF THE ANEMOMETER.

	Above Ground.	Above Sea-level.
1873 to Oct. 12, 1878	75 feet.	90 feet.
1878 to Jan. 1, 1889	86 "	100 "
1889 to May, 1891	100 "	120 "
1891 to Sept. 7, 1895	100 "	208 "
1895 to Aug. 1, 1896	136 "	173 "
1896 to Apr. 30, 1902	82 "	185 "
1902 to Dec., 1903	117 "	220 "

The exposure of the anemometer was very satisfactory during the entire period, excepting from 1896 to 1902, when neighboring buildings obstructed the free movement of the atmosphere over the station. The elevation of the anemometer above sea level was approximately the same from 1871 to 1889, namely, between 90 feet and 100 feet; from 1891 to 1904, with the exception of September, 1895, to July, 1896, the sea-level elevation was increased by approximately 100 feet. Changes in elevation above sea level affect the velocity of movement of the atmosphere no less than changes in elevation above ground. The abrupt increase in the velocity shown from 1890 to 1891 is doubtless due to the change in the sea-level elevation of the anemometer.

Since 1893 a continuous record of wind direction has been maintained without interruption excepting for a few hours at a time when difficulty was experienced with the recording instrument. The hourly changes in wind direction discussed in the following pages are based upon the ten-years' record from 1893 to 1902, unless otherwise stated.

Average Hourly Wind Movement.

The recorded hourly velocities for the twenty-year period from 1881 to 1900 have been reduced to average hourly values in order to determine the periodic variations in velocity during the day. The results are shown in Table LXX, and graphically in Figs. 70 and 71. In Fig. 70 the hourly changes in velocity are given for the months of January, April, July and October, and the average for the entire year. The curves for all months are similar in form. There is a minimum velocity in all months just before sunrise. The velocity rises rapidly to a maximum between two or three in the afternoon, which it maintains approximately for two or three hours, then decreases rapidly to 8 p. m. or 9 p. m., and more slowly to the minimum for the day just before sunrise. The same hourly variation is shown for all months of the year in another manner in Fig. 71. The influence of the diurnal variations in temperature upon the coincident variation in wind velocity is strikingly exhibited in the table and diagrams; the increase in velocity accompanies the increase in temperature throughout the course. The time of maximum rate of

increase and decrease in velocity is coincident with the time of maximum rate of change in temperature, the most rapid increase occurring between

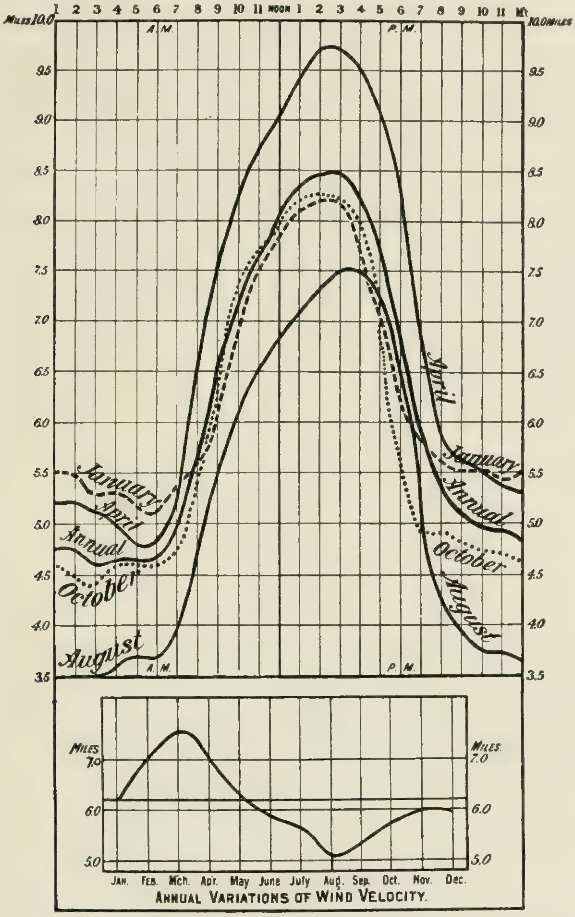


FIG. 70.—Hourly and Annual Variations of Wind Velocity.

Expressed in miles and tenths of miles per hour for the months of January, April, July and October, and for the entire year.

8 a. m. and 10 a. m., and the most rapid decrease between 6 p. m. and 8 p. m.

In the annual fluctuation in velocity, however, a similar relationship does not exist. On the contrary, there is almost a direct inversion of

TABLE LXX.—AVERAGE HOURLY WIND MOVEMENT.

(In miles and tenths.)

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Midn't to 1 a. m. ..	5.5	5.9	6.0	5.2	4.5	4.2	4.0	3.5	4.0	4.6	4.8	5.1	4.8
2 "	5.5	5.8	5.9	5.2	5.0	4.1	4.0	3.5	3.9	4.5	4.8	5.0	4.8
3 "	5.3	5.7	5.8	5.1	4.2	3.6	3.9	3.5	3.9	4.4	4.8	5.0	4.6
4 "	5.3	5.8	5.8	5.0	4.1	3.8	3.8	3.6	3.9	4.6	4.9	5.0	4.6
5 "	5.2	5.8	6.0	4.8	4.2	3.9	3.7	3.7	3.9	4.6	4.8	4.9	4.6
6 "	5.1	5.8	5.9	4.8	4.3	4.0	3.8	3.7	4.0	4.6	4.7	4.9	4.6
7 "	5.4	5.9	6.0	5.2	5.0	4.8	4.3	3.9	4.3	4.7	4.8	5.0	4.9
8 " ..	5.6	6.2	7.0	6.4	5.7	5.7	5.3	4.7	4.9	5.4	5.2	5.2	5.6
9 "	6.1	7.0	8.5	7.6	6.6	6.3	6.0	5.5	5.8	6.2	6.0	5.7	6.4
10 "	6.9	7.8	9.0	8.2	7.1	6.9	6.5	6.0	6.5	7.3	7.1	6.6	7.2
11 "	7.5	8.3	9.3	8.7	7.7	7.4	6.8	6.5	6.8	7.7	7.7	7.2	7.6
Noon.....	7.8	8.7	9.6	9.0	8.2	7.7	7.2	6.8	7.2	7.9	8.1	7.7	8.0
1 p. m....	8.1	9.1	9.9	9.4	8.6	8.1	7.8	7.1	7.5	8.2	8.4	7.8	8.3
2 "	8.2	9.1	9.9	9.7	8.8	8.2	8.0	7.3	7.6	8.2	8.4	8.0	8.4
3 "	8.2	9.1	10.0	9.7	8.9	8.3	8.2	7.5	7.6	8.2	8.2	7.9	8.5
4 "	7.7	8.8	9.9	9.5	8.6	8.2	8.0	7.5	7.5	8.0	7.9	7.5	8.3
5 "	7.1	8.3	9.6	9.1	8.4	8.1	7.6	7.2	7.0	7.1	6.9	6.6	7.8
6 "	6.2	7.3	8.4	8.2	7.6	7.3	7.1	6.4	6.0	5.7	5.9	5.8	6.8
7 "	5.8	6.6	7.2	6.8	6.4	6.1	6.0	5.2	4.8	4.9	5.4	5.5	5.9
8 " .	5.6	6.3	6.6	5.8	5.5	5.1	4.7	4.2	4.4	4.9	5.3	5.4	5.3
9 "	5.5	6.0	6.5	5.7	5.2	4.6	4.4	3.9	4.4	4.8	5.1	5.3	5.1
10 "	5.5	5.9	6.3	5.5	4.8	4.4	4.2	3.7	4.2	4.7	5.0	5.2	5.0
11 " ...	5.4	6.0	6.3	5.4	4.8	4.3	4.0	3.7	4.3	4.7	5.0	5.2	4.9
Midn't. ...	5.5	5.9	6.1	5.3	4.8	4.2	4.0	3.6	4.1	4.6	4.9	5.1	4.8
Means.....	6.2	7.0	7.6	6.9	6.2	5.8	5.6	5.1	5.4	5.8	6.0	5.9	6.1

Table LXX is based on the continuous record of a self-registering anemometer during the 20 years from 1881 to 1900.

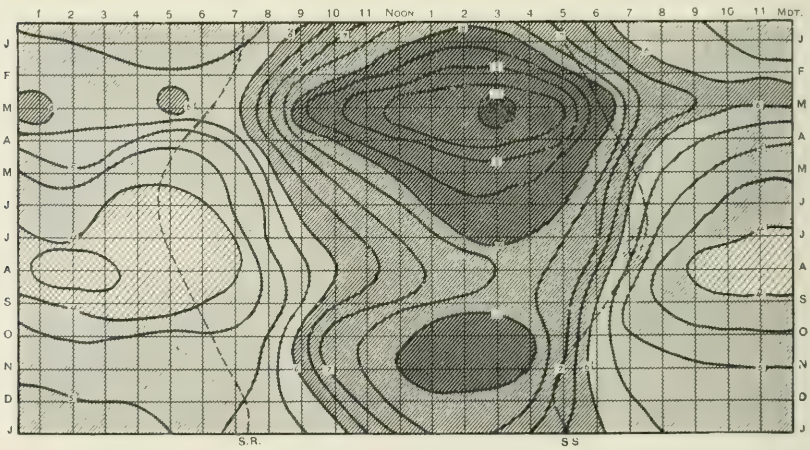


FIG. 71.—Average Hourly Variations in Wind Velocity.

The heaviest shading shows the time of occurrence of the highest average wind velocities for the day. The curved lines mark intervals of half a mile in the average velocity. The dotted lines marked S.R. and S.S. show the time of sunrise and sunset, respectively. The diagram is based on hourly values for a period of 20 years.

the relation existing between temperature and wind velocity. The lightest winds occur in the months of greatest heat, while the highest velocities occur in March, with a slight secondary increase in October and November (see Fig. 71). The annual fluctuations are due to the variations in cyclonic activity at different seasons of the year. The highest average hourly wind velocities occur between 2 p. m. and 3 p. m. in the month of March, when they attain an average velocity of 10 miles per hour. The lowest velocities occur in the early morning hours of June, July and August, when the average falls to about 3.5 miles per hour. This law of increase and decrease is remarkably constant throughout the year and is recognizable at any time when not interrupted by the presence of a well-developed cyclonic or anti-cyclonic disturbance.

Average Daily and Total Monthly Wind Movement.

In Table LXXI the total monthly wind movement for each month of the year from 1873 to 1903 is shown, together with the average daily movement for each year during the same period. As the elevation of the anemometer was changed several times during this period, it is essential to bear in mind the fact in discussing the variations in wind velocities as shown in Table LXXI. No attempt has been made to reduce the records to a single elevation; the changes in elevation are distinctly traceable in the monthly and daily values for the wind movement. Inferences as to fluctuations in the annual velocity should be made with caution. The average daily wind movement is approximately 145 miles for the entire year. The velocity varies from a minimum of 122 miles in August to a maximum of 175 miles per day in March. The following figures represent the average daily wind movement for each month, as derived from hourly observations from 1873 to 1902, a period of 30 years:

AVERAGE DAILY WIND MOVEMENT.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.	Year
Miles............	145	162	175	166	149	142	134	122	129	137	143	142	145

TABLE LXXI.—TOTAL MONTHLY AND AVERAGE DAILY WIND MOVEMENT.

Year.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Monthly Mean.	Average daily movement.
1873..........	3665	3838	6228	5138	4289	4136	3966	3573	3680	4103	4256	4181	4254	140
1874..........	4848	4180	5811	5565	4670	4529	4646	4188	4022	3802	3665	4586	4543	149
1875..........	3571	4136	3977	4891	4990	3792	3435	3310	3353	3687	3257	2959	3780	124
1876..........	4510	4626	5766	4718	4495	4432	4341	3769	4764	4180	4079	4014	4474	147
1877..........	2764	2671	4854	4065	4016	4479	4083	3907	3775	4317	4715	4285	3994	131
1878	5235	4021	5124	4870	4344	4479	4189	3717	3937	4600	4617	5765	4575	150
1879..........	5336	4812	4158	5149	4350	4225	4518	4026	3610	3461	4715	3905	4355	143
1880..........	3442	4585	5295	5398	4764	4644	3949	3876	3629	3939	3640	4661	4318	142
1881..........	3654	4262	6519	5045	3841	3906	3867	3073	3252	3456	4135	3795	4067	134
1882..........	4325	3567	4466	4422	4210	4723	4213	3522	3774	3232	3542	4439	4036	133
1883..........	3471	4054	4753	4583	4993	4076	4184	3861	4110	4213	4061	3634	4166	137
1884..........	4609	4273	4615	5139	4483	3655	4074	3237	3576	3905	3934	3928	4119	135
1885..........	5090	4439	4876	4333	3917	4354	3740	4073	3531	3926	4199	5047	4294	141
1886..........	4789	4821	5847	4085	4235	3802	3508	3680	3442	3796	4708	4028	4228	139
1887..........	4600	4407	5892	4963	3783	4122	4072	3652	3184	4093	3833	4176	4231	139
1888..........	4551	3388	5495	4736	4041	3949	3806	3690	3570	4626	4328	4276	4205	138
1889..........	3928	3808	5336	5455	4198	3900	3948	3945	5140	4669	3831	3714	4323	142
1890..........	4191	3661	4964	3997	3970	3281	3506	3631	3386	3975	3342	4440	3862	127
1891	3740	4385	6033	4430	4828	5112	5502	4399	4008	6125	5937	5766	5022	165
1892..........	6292	6410	7326	6433	5987	5635	4451	4536	4867	5484	6567	5567	5796	191
1893..........	6510	6628	6904	6604	6588	4867	4957	5222	5062	5360	5422	5798	5827	192
1894..........	5413	5553	5872	6351	5880	4654	4960	3880	4731	5808	6213	5054	5364	176
1895..........	6020	7090	7070	6208	5435	4561	4541	4890	4857	5645	5373	6023	5643	186
1896..........	6299	7297	8038	6056	5669	4955	5297	3122	3452	3589	3132	3342	5021	165
1897	4559	3840	4338	3974	4196	3440	3551	2908	3295	4136	3462	3526	3769	124
1898..........	4097	3668	4226	4839	4235	3754	3765	3130	3425	4080	3559	4180	3913	129
1899..........	3840	3946	5040	4077	3650	3489	3355	3948	3362	3415	3197	4036	3780	124
1900..........	3932	4547	4340	3574	4101	3715	3397	3204	3176	3585	3722	3450	3729	122
1901..........	3793	4036	5007	5387	4359	3263	3689	3162	3283	3074	4299	3699	3921	129
1902..........	3874	4829	4594	4963	5932	5598	5098	4606	4754	5197	4781	5940	5014	165
1903..........	6410	6073	4938	6449	5336	5115	5007	4731	4549	6329	4619	6230	5482	180
Average														
1873-1882.....	4135	4070	5220	4926	4397	4334	4121	3696	3780	3878	4062	4259	4240	139
1883-1892....	4526	4365	5514	4815	4444	4189	4079	3870	3881	4481	4474	4458	4425	145
1893-1902.....	4834	5143	5543	5203	5004	4230	4261	3807	3940	4389	4316	4505	4598	151
1873-1902.....	4498	4526	5425	4982	4615	4251	4154	3791	3867	4249	4284	4407	4421	145
Average daily 1873-1902 ..	145	162	175	166	149	142	134	122	129	137	143	142		

Table LXVIII shows the total monthly and average daily wind movement for 31 years, from 1873 to 1903; also the average daily movement for the entire 30 years ending 1902. The figures are based on the continuous record of a self-registering Robinson anemometer.

The average daily movement for an entire year has been as low as 124 miles, as in 1875, and as high as 150 miles, as in 1878, confining our choice of limiting values to the period from 1873 to 1890, during which the elevation of the anemometer remained practically unchanged.

TABLE LXXII.—MAXIMUM WIND VELOCITIES.

Year.	Jan.			Feb.			March			April			May			June		
	Vel.	Dir.	Date	Vel.	Dir.	Date	Vel.	Dir.	Date	Vel.	Dir.	Date	Vel.	Dir.	Date	Vel.	Dir.	Date
1875	23	NW	9	25	SW	3	30	NW	17	25	NW	24	35	W	2	19	SW	27
1876	28	NW	19	40	NW	2	30	NW	28	28	NW	7	20	W	12	24	SE	18
1877	28	E	7	30	NW	12	30	NW	9	25	NE	9	20	NW	22	20	SW	9
1878	36	W	31	24	W	25	36	NW	24	24	NW	6	30	N	31	24	W	11
1879	39	W	4	27	NW	2	36	NW	31	60	NW	3	19	NW	1	36	SE	28
1880	20	NW	20	26	NW	1	28	NW	24	27	NW	30	20	S	21	26	NW	25
1881	19	NE	21	28	NW	23	24	W	4	26	W	5	17	W	2	26	NW	20
1882	28	NW	22	27	NW	10	24	NW	10	25	SW	19	23	SW	28	26	NW	19
1883	22	NW	14	22	NW	4	28	NW	20	28	SW	5	23	SW	26	22	SW	10
1884	24	W	2	31	NW	28	26	NW	30	28	NW	3	23	W	2	18	SW	24
1885	37	NW	17	26	NW	10	22	NW	20	31	NW	29	19	W	4	21	NW	5
1886	27	SE	4	36	NW	26	25	NW	21	28	SW	1	20	SW	27	18	NW	26
1887	28	NW	17	34	NW	11	27	NW	29	24	NW	29	20	E	31	24	SW	2
1888	30	NW	26	24	NW	15	33	NW	12	28	NW	14	22	S	4	28	SW	23
1889	24	NW	7	24	NW	7	25	NE	4	35	NE	26	35	NW	10	26	S	1
1890	28	SW	13	24	NW	21	24	NW	2	30	SW	7	24	NW	20	24	SW	12
1891	28	SW	25	26	S	28	26	NE	27	20	SW	23	25	N	22	40	NE	4
1892	37	E	6	36	NW	12	42	NW	10	35	NW	16	32	NW	2	42	SW	27
1893	39	NW	10	45	NW	19	36	NW	15	42	NW	15	43	W	23	28	NW	22
1894	48	W	30	42	NW	16	37	W	23	38	W	5	33	W	7	40	N	12
1895	36	W	27	42	W	8	37	NW	28	26	NW	9	26	NW	27	36	NW	5
1896	35	NE	24	40	W	11	50	S	19	36	W	3	35	N	5	30	S	8
1897	28	W	23	30	W	2	25	W	24	29	NW	26	26	SE	1	22	W	1
1898	32	SW	23	28	SW	16	24	NW	31	25	E	19	24	N	8	22	N	19
1899	24	W	27	30	N	16	30	W	29	30	W	16	30	NW	16	20	N	1
1900	26	W	26	30	W	13	25	W	2	20	N	4	21	E	28	19	N	30
1901	24	W	19	22	SW	24	25	E	10	24	NE	14	24	SE	22	22	N	22
1902	24	E	21	33	W	2	27	SW	13	30	NE	8	32	W	28	30	NW	26
1903	42	W	30	45	W	5	32	W	1	31	NW	8	33	W	22	26	N	11
1875–1902. Aver. vel. and prevail. direc.	29.4	NW	..	30.4	NW	..	29.7	NW	..	29.5	NW	..	25.8	W	..	26.2	NW	..
Highest vel. with direc.	48	W	1894	45	NW	1893	50	S	1896	60	NW	1879	43	W	1893	42	SW	1892

Year.	July			Aug.			Sept.			Oct.			Nov.			Dec.			Annual-greatest		
	Vel.	Dir.	Date	Vel.	Dir.	Date	Vel.	Dir.	Date	Vel.	Dir.	Date	Vel.	Dir.	Date	Vel.	Dir.	Date	Vel.	Dir.	Date.
1875	24	NW	18	25	S	6	20	W	20	28	NW	30	23	NW	17	25	W	13	35	W	May 2
1876	20	SE	11	16	NE	2	35	NE	17	24	NW	15	24	SW	2	32	W	9	40	NW	Feb. 2
1877	20	SW	3	16	NE	1	20	NW	3	30	NW	4	36	E	24	30	W	13	36	E	Nov. 24
1878	33	SW	9	20	SW	1	25	SE	13	45	SW	23	30	NW	23	40	W	11	45	SW	Oct. 23
1879	30	NW	11	20	S	22	18	W	8	24	NW	28	30	NW	20	24	W	15	60	NW	Apr. 3
1880	22	W	20	24	NW	25	17	NW	30	24	NW	23	26	NW	26	22	NW	22	28	NW	Mar. 5, 24
1881	23	NW	13	20	NW	1	16	SE	15	19	N	4	24	NW	4	24	NW	7	28	NW	Feb. 23
1882	20	E	4	14	NE	28	18	SW	14	16	NW	25	23	NW	13	26	NW	7	28	NW	Jan. 22
1883	23	W	7	20	SW	2	21	NE	12	24	W	30	28	NW	12	26	NW	28	28	SW	Apr. 5
1884	32	NW	31	17	NW	30	18	S	24	26	SW	22	27	SE	23	28	NW	9	31	NW	Feb. 28
1885	24	SW	26	18	NE	25	22	NW	23	24	S	13	23	SW	5	26	NW	7	37	NW	Jan. 17
1886	23	NW	31	17	W	30	21	SW	26	20	NW	15	28	NW	25	26	NW	2	36	NW	Feb. 26
1887	39	NW	18	24	NW	22	20	N	23	30	NW	21	28	NW	11	33	NW	29	39	NW	July 18
1888	23	W	12	45	SW	8	18	NW	27	30	SW	1	25	NW	4	36	NW	18	45	SW	Aug. 8
1889	24	N	13	18	NE	27	30	N	10	24	N	7	22	NE	18	24	W	26	35	NW	May 10
1890	18	NE	16	26	N	22	18	NE	29	28	N	24	24	NW	22	39	NE	17	39	NE	Dec. 17
1891	36	NW	15	36	NW	12	24	SW	6	36	NW	26	48	S	23	40	NW	16	48	S	Nov. 23
1892	36	SW	3	35	NW	10	38	NW	26	36	NW	29	42	NE	15	30	NW	24	42	NW	Mar. 10
1893	42	NW	26	42	SE	29	36	NW	16	40	SE	13	32	SE	27	33	NW	1	45	NW	Feb. 19
1894	26	W	29	20	SE	18	36	NW	10	32	NW	10	38	NW	25	36	NW	27	48	W	Jan. 30
1895	35	NW	27	36	NW	31	32	W	13	35	NW	13	28	NW	26	42	S	26	42	W	Feb. 8
1896	36	N	27	25	N	12	36	E	29	19	N	12	22	W	13	25	W	9	50	S	Mar. 19
1897	29	E	17	22	SW	15	17	N	23	25	NE	25	26	W	9	22	W	31	30	W	Feb. 2
1898	20	NE	12	20	N	18	19	W	7	30	SE	18	20	W	10	54	E	4	54	E	Dec. 4
1899	19	SW	5	20	NW	13	20	NW	8	26	NE	31	21	N	11	24	W	24	30	N	Feb. 16
1900	18	SW	7	26	W	12	20	W	12	21	NE	13	29	NW	21	24	W	5	30	W	Feb. 13
1901	24	NE	7	21	NE	6	17	W	13	19	W	23	32	NE	24	27	W	10	32	NE	Nov. 24
1902	70	W	20	30	SW	6	36	NW	9	26	NW	14	32	W	28	31	NW	5	70	W	July 20
1903	46	W	12	24	SE	27	34	W	17	42	N	9	29	NW	24	41	NW	13	46	W	July 12
1875–1902. Aver. vel. and prevail. direc.	28.2	NW	..	24.0	NW	..	23.9	NW	..	27.2	NW	..	28.2	NW	..	30.3	NW	..	..	..	
Highest vel. with direc.	70	W	1902	45	SW	1888	38	NW	1892	45	SW	1878	48	S	1891	54	E	1898	70	W	July 20 1902

Table LXXII shows the highest wind velocity recorded during each month and year from 1875 to 1903, together with the direction of the wind at the time of maximum velocity and the date of occurrence. The velocities are expressed in miles per hour, and are calculated from the greatest wind movement during any five-minute period from midnight to midnight.

Maximum Wind Velocities.

In the preceding paragraphs the total wind movement over the station for an entire month, and the average hourly and average daily movement were alone considered. In Table LXXII a record will be found of the highest velocity of the wind attained in any 5-minute period during each month and year from 1875 to 1903, together with the accompanying direction of the wind and the date of occurrence. In determining the maximum wind velocity for the day, the sheet contain-

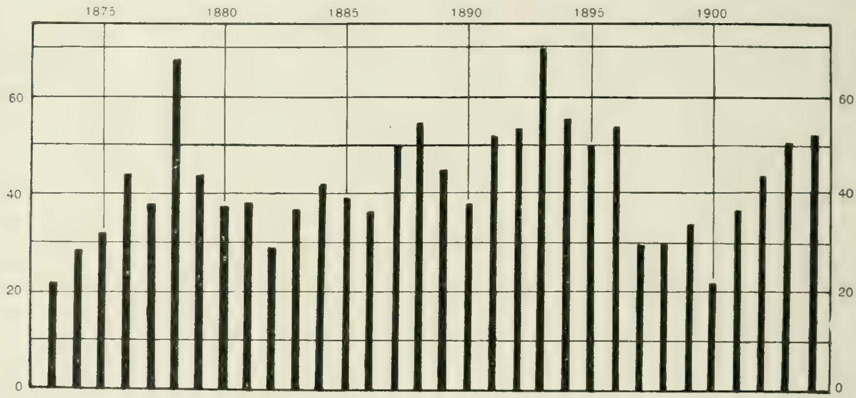


Fig. 72.—The Frequency of Storm Winds.

The diagram shows the variations in the annual frequency of winds exceeding 25 miles per hour.

ing the continuous record of the anemometer is examined and the five-minute interval selected during which the velocity is greatest. The number of miles or fractions of a mile registered during this 5-minute period is then multiplied by 12 in order to obtain the rate of movement per hour, or what is usually termed the hourly velocity of the wind. All of the daily records since 1875 have been carefully examined and the highest velocity recorded during each month selected and entered in Table LXXII, at the same time noting the date of occurrence and the direction of the wind during the selected 5-minute period. An examination of the table shows that high winds are not confined to any particular season of the year, but have occurred in all months. The high winds of

the winter months occur in connection with the well-defined cyclonic disturbances, while the high velocities of the summer months accompany the thunderstorms, or the tornado, in the rare instances of its occurrence in this vicinity. The annual variations of the maximum velocity are shown in Fig. 72.

The highest velocity of the wind recorded at the Baltimore Station of the U. S. Weather Bureau since 1875 occurred during the storm of July 20, 1902, when the wind blew at the rate of 70 miles per hour for five minutes. Further particulars of this storm, which was one of the most destructive ever visiting this vicinity, will be found in a later section of this report. Selecting the highest recorded velocities, in miles per hour, for each month of the year, we have the following comparative figures:

HIGHEST MONTHLY VELOCITIES.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Highest vel....	48	45	50	60	43	42	70	45	38	45	48	54	70
Direction......	W	NW	S	NW	W	SW	W	SW	NW	SW	S	E	W
Year........	1894	1893	1896	1879	1893	1892	1902	1888	1892	1878	1891	1898	1902
Day....	30	19	19	3	23	27	20	8	26	23	23	4	....
Av. vel. of max.	29	30	30	30	26	26	28	24	24	27	28	30	28

The average of all maximum velocities during the 28 years from 1875 to 1902, as shown in the last line of the above table, indicates a remarkably uniform value for this factor, throughout the year. The highest monthly average velocity (30) differs from the lowest (24) by only 6 miles. The lowest velocities occur in August and September, and the highest in February, March, April and December. The fact that the September records show the lowest average velocities for storm winds is significant in view of the popular association of the so-called "Equinoctial" storms with this month.

As already stated, wind velocities are generally expressed in terms of the rate per hour based upon the actual velocity during a five-minute period. By basing the rate per hour upon the duration of the mile made in the shortest time, we obtain what is officially designated as the *extreme* velocity. By this method we are more liable to obtain the

velocity in brief gusts of wind, velocities which are lost when the hourly rate is based upon the movement during a period of five minutes. As much of the destruction due to high winds is wrought during these brief gusts, or squalls, the *extreme* velocity is a factor of great importance. It is, in nearly all cases, higher than the *maximum;* it cannot be lower. There is no fixed relation between the two velocities; it may be of interest, however, to show to what extent they have differed from one another. Basing our inquiry upon the official record of the monthly maximum and extreme velocities during the period from 1888 to 1903, we have the following comparative figures:

RELATION BETWEEN MAXIMUM AND EXTREME VELOCITIES.

(In miles per hour.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Maximum	48	45	50	42	43	42	70	45	38	42	48	54
Extreme	60	55	60	50	48	50	75	52	50	50	60	60
Difference	12	10	10	8	5	8	5	7	12	8	12	6

This relationship may be expressed by another method. In place of selecting the highest maximum and highest extreme velocities for each month, we may examine all cases of high winds occurring in a stated time and note the difference between the maximum and extreme velocities. This has been done for a period of three years with the following result:

DIFFERENCES BETWEEN MAXIMUM AND EXTREME VELOCITIES.

(In miles per hour.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Average diff	4.5	4.5	4.3	4.3	3.4	3.6	7.8	3.9	4 8	3.6	5.0	4.2	4.5
Greatest "	12	10	8	8	5	12	17	10	16	10	8	8	17
Least "	1	1	2	2	2	0	1	1	1	1	1	2	0
No. of cases	18	29	22	11	17	14	15	7	13	17	16	16	195

The highest wind velocities generally occur in connection with a northwest wind in all months of the year. These winds usually accompany a rising barometer and occur a short time after the shift in the

wind which follows the turn in the barometer. While northwest is the usual direction of the storm wind, all directions of the compass are represented. In Table LXXII there are 348 records of high winds covering a period of 29 years; placing these in the order of frequency of the directions from which they came, we have the following relative positions for the entire year:

RELATIVE FREQUENCY OF HIGH WINDS.

Direction of wind	NW	W	SW	NE	N	SE	E	S
Percentage of frequency	41	20	12	8	7	4	4	4

The same order of frequency obtains practically in all months of the year. In nearly three-fourths of all instances of storm winds, the direction is from some point between southwest and northwest. In only 12 per cent of instances is the direction from some point between east and south. High winds from the north or from the east are of comparatively rare occurrence at Baltimore.

Frequency and Duration of Stated Wind Velocities.

The hourly wind velocities during a period of five years (namely, from 1893-96 and 1903) were tabulated into groups in order to determine the relative frequency of stated velocities. The result is shown in the following table, in which the frequencies are expressed in terms of percentages of the total number of hours in each month:

FREQUENCY OF STATED WIND VELOCITIES.

(In percentage of possible number of hours per month.)

Miles per hour	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
0-5	37.6	31.2	33.7	28.8	35.3	41.5	44.3	49.0	45.3	41.8	39.3	40.7	39.1
6-10	35.7	35.2	36.4	40.7	43.0	44.4	43.1	39.7	38.5	37.6	35.6	35.3	38.8
11-15	15.8	15.7	16.2	19.9	15.6	12.2	10.8	9.1	13.2	13.8	16.1	15.7	14.5
16-20	6.4	9.9	8.3	8.2	4.9	1.8	1.3	1.3	2.5	4.6	6.5	6.3	5.2
21-25	2.8	4.9	3.5	1.9	0.7	0.1	0.1	0.3	0.4	1.7	2.2	1.5	1.6
26-30	1.2	2.1	1.4	0.5	0.4	....	0.1	0.2	0.2	0.3	0.2	0.4	0.6
31-40	0.3	0.9	0.3	....	0.05	....	....	0.1	0.06	0.1	0.2	0.03	0.1
41-50	0.03	....	0.03	....	...	....	....	...	....	....	....	....	0.0

Winds of 10 miles per hour and under prevail during about 78 per cent of the total number of hours of the year; winds of 11 miles to 20 miles during less than 20 per cent. Hence the total duration of velocities exceeding 20 miles per hour is only about 2.3 per cent of the entire year, or about eight and a third days. Storm winds, or winds exceeding 25 miles per hour, prevail during about 62 hours in an average year.

Average Duration of Storm Winds.

It will be seen from the statements in the preceding paragraph that winds having a velocity exceeding 25 miles per hour are of brief duration. The duration decreases rapidly with increase in wind velocity. The rate of decrease may be readily judged from the figures in the above table representing the annual relative frequency of stated velocities. Basing our calculations upon the same period of five years employed in determining the relative frequency of stated velocities, we obtain some interesting figures defining the average duration of storm winds.

AVERAGE DURATION OF STORM WINDS.
(In hours and minutes.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Total annual duration...	23.35	43.35	28.25	12.25	5.35	0.25	0.50	4.10	3.40	11.10	9.50	13.05	156.40
Average frequency..	6.2	9.2	7.6	5.0	4.4	2.0	2.6	1.4	2.6	4.2	4.8	4.4	54.4
Duration per storm......	3.50	4.40	3.40	2.30	1.20	0.12	0.20	3.00	1.25	2.40	2.00	3.00	2.50
Greatest duration....	19.00	46.00	23.00	16.00	7.00	.35	.30	18.30	7.00	9.10	6.00	19.00	46.00

In the winter and early spring months a storm wind usually continues from three to four hours. The duration rapidly diminishes on the approach of summer, reaching a minimum in June and July, when the average duration is only a few minutes. The high winds of summer usually occur in connection with thunder squalls of brief duration, while those of winter, spring and fall accompany the passage of well-defined cyclonic storms. The comparatively long duration of August storm winds in the above table is due entirely to the severe gulf storm of August 28-29, 1893, during which the wind blew a gale for many hours,

a duration which would be considered long even for a winter gale of the severest type. Neglecting this storm, the August average duration for the remaining four years is about 35 minutes.

During the passage of the Gulf storm of February 7-10, 1895, the wind blew at Baltimore with a velocity exceeding 25 miles per hour for about 46 consecutive hours. It then fell below the storm velocity for about 12 hours and again went above 25 miles per hour for another period of 12 hours. It is one of the longest storm periods on record at Baltimore. The storm originated in the Gulf of Mexico on the 6th, and moved rapidly eastward and northward along the Atlantic coast from Florida to the Gulf of St. Lawrence, the center passing just eastward of Baltimore on the 8th, with a maximum velocity of 42 miles per hour from the west. The barometric gradient between the center of the storm and the center of the area of high pressure to the west and northwest was very great throughout its course, amounting at one time to about two and a half inches. The *extreme* velocity of 50 miles per hour was reached on the 8th at about noon.

As the summer high winds occur mostly in connection with thunderstorms, their time of greatest frequency, and hence greatest probability, is from 3 p. m. to 4 p. m. The winter, spring and fall storm winds, accompanying cyclonic disturbances which occur at any hour of the day, also have a well-marked tendency to fall within the early afternoon hours. This may easily be explained by supposing that the cyclonic winds are augmented at these hours to a maximum extent by the diurnal wind movement.

Gales.

A gale is technically defined by a wind velocity of 40 miles, or over, per hour. Such winds have been recorded on 42 occasions at the Baltimore office of the U. S. Weather Bureau since 1873. They have been of comparatively great frequency in some years, notably in 1893, which is credited with nine; there were seven in 1903. In half the years since 1873, none were recorded. The highest velocity registered in the years from 1880 to 1887 was 39 miles. As is the case with most high winds,

TABLE LXXIII.—SUMMARY OF WIND VELOCITIES.
(1873–1902.)

	Means.					Maxima.					Storm winds.*		
	Mean.	Highest.	Year.	Lowest.	Year.	Mean max.	Highest.	Year.	Lowest.	Year.	Average number.	Max. no.	Year.
January	6.0	8.8	1893	3.7	1877	29	48	1894	19	1881	4.4	10	1878
February	6.7	10.8	1896	3.9	1877	30	45	1893	22	1883 1901	5.5	12	1895
March	7.3	10.8	1896	5.3	1875	30	50	1896	22	1885	6.7	13	1881
April	6.9	9.2	1893	5.0	1900	30	60	1879	20	1891 1900	5.2	13	1880
May	6.2	8.9	1893	4.9	1899	26	43	1893	17	1881	2.9	9	1878 1893
June	5.9	7.8	1892	4.5	1901	26	42	1892	18	1884 1886	2.2	5	1877 1879
July	5.6	7.4	1891	4.5	1899	28	70	1902	18	1890 1900	1.8	4	1878 1896 1901
August	5.1	7.0	1893	3.9	1897	24	45	1888	14	1882	1.2	4	1887
September	5.4	7.1	1889	4.4	1900	24	38	1892	16	1881	1.4	5	1889 1896
October	5.7	8.2	1891	4.1	1901	27	45	1878	16	1882	3.0	7	1894
November	6.0	9.1	1892	4.4	1896	28	48	1891	20	1898	3.7	9	1886
December	5.9	8.1	1895	4.0	1875	30	54	1898	22	1880 1897	3.9	8	1885 1887
Year	6.1	8.0	1893	5.1	1900	28	70	1902	14	1882	42.0	70	1893

* Winds exceeding 25 miles per hour.

gales blow mostly from the northwest or west. Of the 42 instances referred to above, the relative frequency of the points of the compass from which they blew is as follows:

DIRECTION OF THE WIND IN GALES.

	NW	W	S	SW	SE	NE	N	E	Total
Number of gales	15	13	4	3	2	2	2	1	42

The distribution of gales by months shows that they have been most frequent in February. The month of "equinoctial storms" is the only month without a gale to its credit in 30 years.

FREQUENCY OF GALES IN 30 YEARS.

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
2	10	3	2	2	3	4	2	0	3	5	6	42

Prevailing Hourly Wind Directions.

We have seen in preceding paragraphs that there is a well-defined diurnal fluctuation in the velocity of the wind. Without a close observation of diurnal changes of direction in the locality of Baltimore, a well-marked periodicity would scarcely be suspected. Such is the fact, however, as demonstrated by a reduction of the hourly observations for a period of ten years. The results are shown statistically in Table LXXIV and graphically in Plate XI, Fig. 73. A well-defined diurnal period was

TABLE LXXIV.—PREVAILING HOURLY WIND DIRECTION.

Hours	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
1 A. M.	NW	W	NW	W	W	SW	SW	SW	SW	N	W	W	W
2	SW	W	NW	W	W	SW	SW	SW	NW	N	W	W	SW
3	SW	W	NW	NW	SW	SW	SW	N	NW	NW	W	NW	NW
4	W	NW	W	NW	NW	SW	SW	NW	N	NW	NW	W	NW
5	W	W	W	W	NW	SW	SW	NW	N	N	NW	W	W
6	W	W	W	W	N	SW	SW	NW	N	NW	N	W	W
7	NW	NW	W	W	NE	SW	SW	N	N	N	NW	W	NW
8	W	W	W	E	N	SW	SW	N	N	N	W	W	W
9	W	W	SW	N	SW	SW	SW	SW	NE	NW	N	W	SW
10	W	W	NW	N	SW	N	SW	SW	E	E	N	SW	SW
11	W	W	E	SE	SE	W	SW	N	N	E	SW	SW	SW
Noon	W	W	SE	SE	SE	SE	SW	SE	E	E	W	NW	SE
1 P. M.	W	W	SE	SE	SE	SE	SE	SE	SE	SE	SW	NW	SE
2	W	NW	SE	SE	SE	SE	SW	SE	SE	SE	W	W	SE
3	W	W	SE	SE	SE	SE	SE	SE	SE	SE	SW	SW	SE
4	W	NW	SE	SE	SE	SE	SE	SE	SE	SE	SE	W	SE
5	W	W	SE	SE	SE	SE	SE	SE	SE	SE	SE	W	SE
6	W	W	SE	SE	SE	SE	SW	SE	SE	SE	SE	W	SE
7	NW	W	E	SE	SE	SE	SW	SE	SE	SE	SE	NW	SE
8	W	W	W	SE	SE	SE	SW	SE	SE	SE	W	W	SE
9	W	NW	NW	SE	SE	S	SW	SW	SW	E	W	NW	SW
10	NW	W	NW	SE	SE	SW	SW	SW	SW	E	W	W	SW
11	NW	W	NW	SE	SE	SW	SW	SW	SW	NW	W	NW	SW
Midnight	SW	W	NW	W	SW	SW	SW	SW	SW	N	N	W	SW
Prevail. direction	W	W	NW	SE	SE	SW	SW	SE	SE	SE	W	W	SE

Table LXXIV, showing the prevailing direction of the wind at the hours stated in the first column, is based upon a record of ten years, extending from 1893 to 1902.

not at first expected to be revealed by the average hourly values which included all the observations of the year, or even all of any particular month. Hence the first attempt to detect a periodic movement was made by selecting days in the months of January, April, July and October, during which the skies were prevailingly clear, and the wind movement was light. This was done with a view to eliminating the influence

of neighboring cyclonic disturbances. The result of such classification is shown in Fig. 74 for January, the diagram being based on ten selected days during which the sunshine exceeded 90 per cent of the possible amount, and the wind movement was less than 100 miles. The wind direction observations were classified into morning and afternoon winds, the former class including the hours from midnight to noon, the latter from noon to midnight. A prevailing westerly wind during the morning hours and an easterly wind during the afternoon hours was so clearly revealed in all months in these diagrams that the hourly observations for each hour and for the entire period of ten years were tabulated and charted, with the result shown in Table LXXIV and Fig. 73. These tables and diagrams reveal some interesting and probably unsuspected facts concerning the daily fluctuations in the wind direction at Baltimore. A well-defined diurnal periodicity appears in all seasons of the year when the local conditions are not influenced by the presence of cyclonic disturbances. This is quite as well marked on cold winter days as in the summer time. Even by employing all observations, the average of all conditions of the weather, this periodic movement is conspicuous excepting in the winter months of December, January and February, when the cyclonic winds almost completely mask the periodic movement.

An examination of Fig. 73 shows a prevailing wind from some quarter between northwest and southwest at all hours between midnight and 11 a. m., with a very few exceptions when they are from the north. This is true for all months of the year. In January, February and December these westerly winds continue throughout the day. In all other months there is an abrupt change in the direction to the southeast about noon; a little earlier in March, April and October and a little later in July and November. The southeast wind then continues without interruption to an early evening or a night hour, when the direction returns quite as abruptly to the southwest or west. The hour of return to the morning direction varies more than the change from the morning to the afternoon direction. The southeast returns to southwest in July as early as 6 p. m.; in April and May as late as 11 p. m. The southeast or afternoon direction is maintained, accordingly, for a minimum period

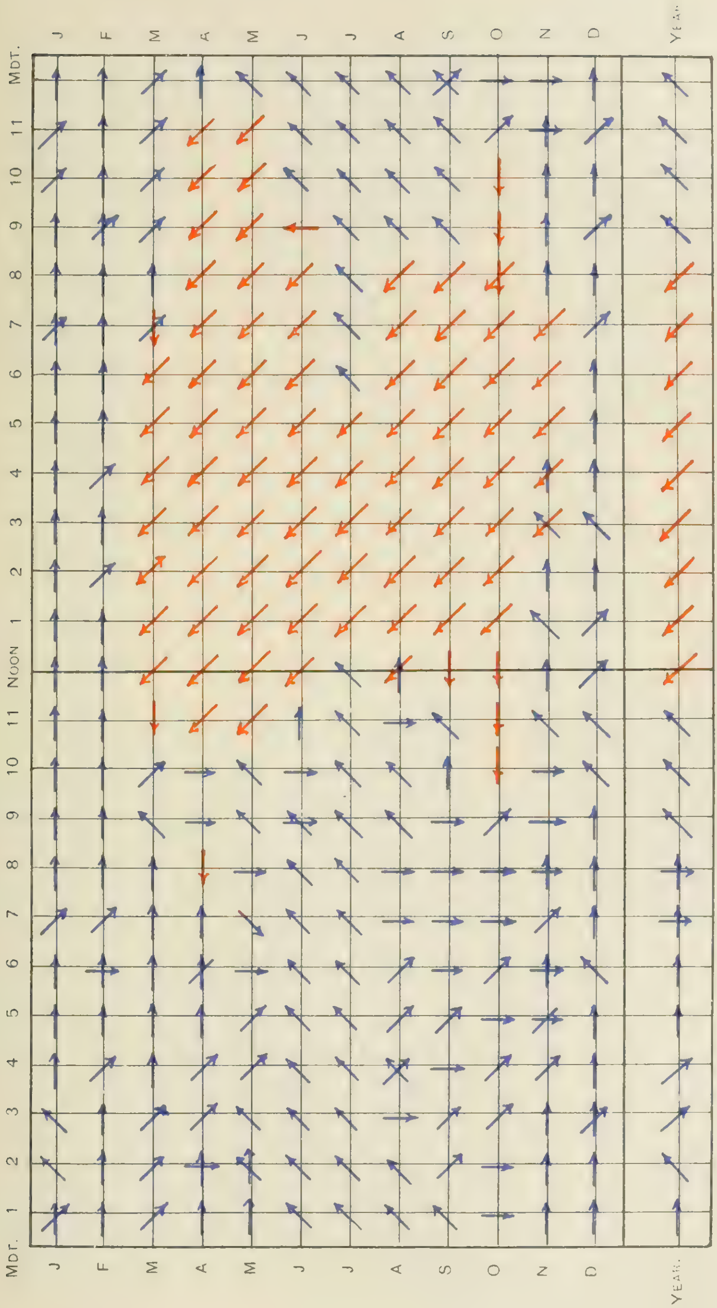


Fig. 73.—Average Hourly Wind Direction.

Based on hourly values for ten years. The westerly winds are in blue, the easterly in red. The diagram shows an abrupt change in direction from westerly to easterly at about noon during all months excepting those of the winter season.

of 5 hours, as in July, to a maximum of 13 hours, as in April, May and October. For the year as a whole, the southwest wind changes to a southeast at noon, maintains this direction until 8 p. m., and then returns to the southwest. The southwest becomes a west or northwest wind from 1 a. m. to 8 a. m., and then southwest again from 9 a. m. to 11 a. m. These hourly changes are surprisingly uniform throughout the year when prevailing directions for a long period are considered, or on quiet days, for short periods of only a few days.

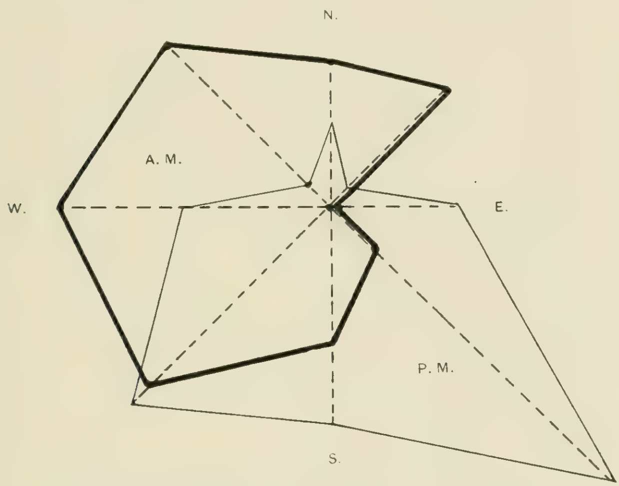


Fig. 74.—Prevailing Morning and Afternoon Wind Directions in January.

The heavy black lines indicate the prevailing winds during the hours from midnight to noon; the light lines show the prevailing winds during the hours from noon to midnight on selected days in January with a light wind and bright sunshine.

In the figure based on the rougher grouping into morning and afternoon directions, the percentage of frequency of occurrence of the wind from each quarter is also shown. Fig. 74 indicates that even in midwinter, represented by the month of January, the morning winds are distinctly west of the north and south line, and the afternoon winds mostly to the east. In Fig. 73, which is based on all observations during a period of ten years, the winds are westerly in January, February and December, both morning and afternoon, as stated above. A feature especially worthy of note is the abrupt change from southwest to south-

east about midday. The change from northwest or west to southeast, and in the reverse order, is made without lingering in the south. A prevailing south wind is not revealed in the diagrams or table for even an hour in any month of the year.

It is difficult to assign a satisfactory cause for this daily periodic movement in the vicinity of Baltimore. The first explanation which is suggested is that it is a land and sea breeze effect. The station is, however, too far removed from a body of water sufficiently large to produce the effect, even at the season of the year when contrasts in temperature between land and water are strongest. The harbor presents a comparatively small water area in Patapsco River, which is in turn twelve to fifteen miles from Chesapeake Bay, while the station is fully a mile distant from the harbor. These facts of local conditions make it extremely improbable that the winds are the effect of an interchange of air between land and water areas. The suggestion arises whether the fluctuations are an integral part of the diurnal cyclone described in the preceding section on pressure changes. To demonstrate this would require a similar discussion of the hourly changes in direction at many widely scattered stations, especially at points somewhat nearer the path of the center of the diurnal cyclone, and on both sides of the equator.

Prevailing Monthly and Annual Directions.

In view of what has been presented in the foregoing paragraphs concerning the hourly changes in the direction of the wind, it becomes obvious that the choice of hours of observation is an important matter in determining the prevailing monthly and annual direction of the wind at any given locality. Most systems of observations, before the days of continuously recording instruments, provided for three eye observations: one about 7 in the morning, another about 3 in the afternoon, and the third at about 9 in the evening. This combination yields a very fair value for the average direction for the day. The prevailing directions based on two daily observations from 1892 to 1903 are placed alongside of the prevailing directions computed from three daily observations and from hourly observations covering the same period. The

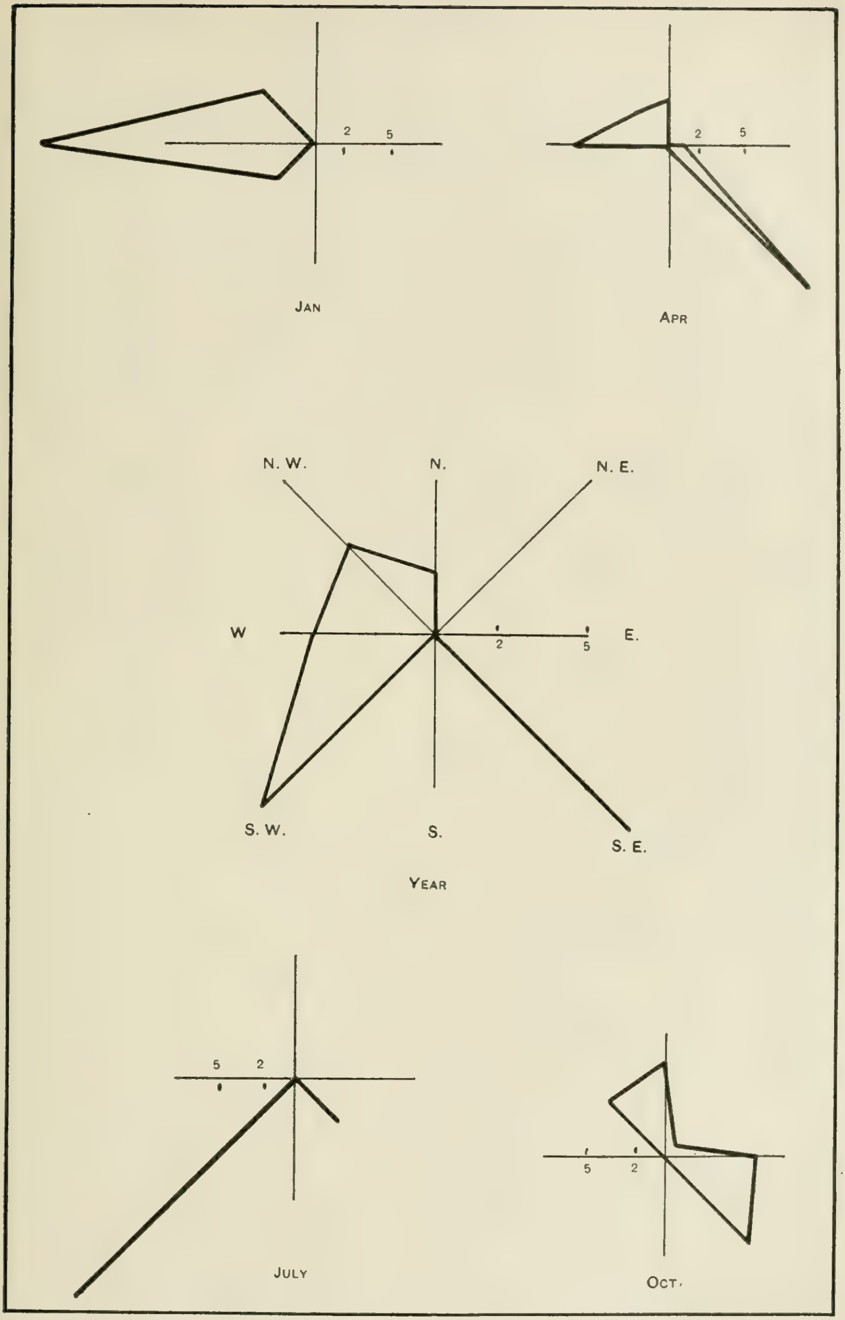


FIG. 75.—Relative Frequency of Prevailing Wind Directions.

The diagram shows the relative frequency of the prevailing directions of the wind in the months of January, April, July and October, and in the year. For example, for the month of July, the prevailing directions during a period of ten years were confined to southwest and southeast winds; in January, the prevailing winds were always westerly during the same period, etc.

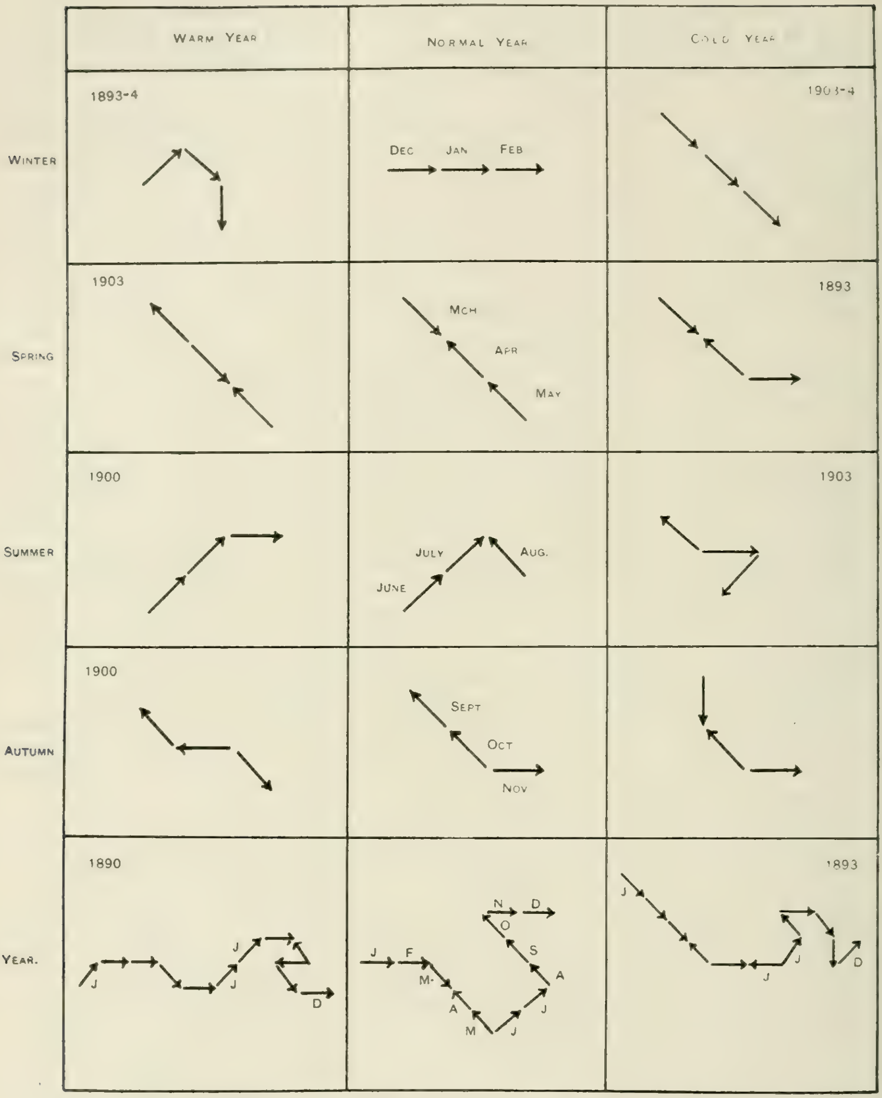


Fig. 76.—Prevailing Monthly Directions of the Wind in Warm, in Normal and in Cold Seasons and Years.

differences are marked only in August, September and October. By the system of two daily eye observations we obtain a prevailing north

wind in September and northwest in October, whereas the hourly observations show a prevailing direction from the southeast during both months. The resultant prevailing directions based on three daily observations agree somewhat more closely with those derived from hourly observations, the chief divergence occurring in August and October. The annual path pursued is best represented by the diagram in Fig. 76, which is based on 24 hourly observations.

The prevailing monthly directions derived from the three series of observations are as follows:

PREVAILING DIRECTIONS.

	Jan.	Feb.	Mar.	Apr	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.	Year
7 a. 3 p. 9 p.	W	W	W	SE	SE	SW	SW	SE	SE	N	W	W	W
8 a. 8 p.	W	W	NW	SE	SE	SW	SW	SW	N	NW	NW	NW	NW
Hourly observ't'ns	W	W	NW	SE	SE	SW	SW	SW	SE	SE	W	W	W,SE

There is a fair degree of uniformity from year to year in the prevailing directions of the wind for the same months. The extent of the departure from the average direction is indicated in Fig. 76, in which the prevailing directions are shown for seasons and a year with a normal temperature, a well-marked temperature below the normal and for those well above the normal in temperature. In each case these seasons and years have been selected from the period from 1893 to 1904, and hence the prevailing directions are based on hourly observations. An inspection of the figure will show that in nearly all cases there is an unusual percentage of northwest winds in the cold seasons, and a predominance of southerly winds (southwest to southeast) in the warmer seasons.

This is in harmony with the results obtained by determining the average temperature of winds from each quarter. Selection was made of a number of days in each of the months of January, April, July and October, during which the wind blew from the same quarter all or most of the day. This was repeated for each of the eight points of the compass. The average temperature of these days was when computed from the hourly observations. It was not always possible to find days during which the wind blew from the same quarter more than half the day; in

such cases it was necessary to admit days with a direction 45° on either side of the desired point of the compass.

In the winter months, the southeast winds are the warmest; in the

TABLE LXXV.—PREVAILING MONTHLY AND ANNUAL DIRECTION OF WIND.

Year.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
1871	NE	NE	NW	W	NE	SW	NW	SW	N	NW	NW	SW	NW
1872	NW	NW	NW	W	NW	SW	SW	W	N	NW	NW	W	NW
1873	NW	NW	NW	NW	NE	SE	SW	NE	N	NW	NW	NW	NW
1874	NW	NW	NW	NE	SE	SW	SW	N	NE	NW	NW	NW	NW
1875	NW	NW	SE	NW	SE	S	S	NE	SW	NW	N	NE	NW
1876	SW	NW	NW	NW	SE	SE	NW	SE	NE	NW	NW	NW	NW
1877	NW	NW	NW	NE	NW	SE	SW	SE	SE	NW	NW	SW	NW
1878	NW	W	NW	NW	NW	W	SW	NW	E	NW	W	W	NW
1879	NW	W	NW	NW	SE	SW	S	W	SE	SE	NW	E	NW
1880	NW	NW	NW	NW	S	W	S	S	NW	SE	NW	NW	NW
1881	W	NW	W	W	SE	W	W	N	SE	S	NW	W	W
1882	NW	NW	NW	NW	S	S	S	S	N	NE	NE	NW	NW
1883	NW	NW	NW	N	SE	S	SW	N	NE	N	N	NW	NW
1884	W	NW	NW	NW	NW	SE	NW	N	S	N	NW	N	NW
1885	NW	NW	NW	NW	NE	NW	SE	SW	N	N	NW	NW	NW
1886	N	NW	NW	NE	NW	SE	SW	NW	S	NW	NW	NW	NW
1887	NW	NW	NW	NW	SE	S	S	N	N	NW	NW	NW	NW
1888	NW	NW	NW	NW	SE	NW	S	SW	N	NW	NW	NW	NW
1889	NW	NW	NW	NE	SE	SW	SW	SW	NE	NE	NW	NE	NW
1890	SW	NE	NW	NE	S	S	S	S	NE	NW	NW	NW	NW
1891	NW	NW	NE	NW	NE	NW	SW	NW	NW	NW	NW	NW	NW
1892	NW	NE	NW	NW	NW	SW	SW	NW	SE	NW	NW	NW	NW
1893	NW	NW	NW	SE	W	E	SW	SE	W	NW	N	SW	NW
1894	NW	N	NW	NW	SE	SW	SW	SE	NE	NW	NW	NW	NW
1895	W	NW	NW	SE	SE	E	NW	SW	N	N	N	N	N
1896	W	W	NW	SE	SW	SW	SW	N	SW	N	SW	W	SW
1897	W	W	E	W	NW	NW	W	NW	N	N	W	NW	W
1898	W	W	E	W	SE	SW	SE	SW	SW	SE	W	W	W
1899	SW	W	E	SE	SE	N	SW	NE	SE	E	NW	W	SE
1900	SW	W	W	NW	W	SW	SW	W	SE	E	NW	W	W
1901	W	W	W	N	E	SE	SW	S	N	SE	W	NW	W
1902	W	W	W	W	SW	NW	SW	SW	NW	NW	N	NW	W
1903	W	W	SE	NW	SE	SE	W	NE	NW	NW	NW	NW	NW
1871-1880	NW	NW	NW	NW	SE	SW	SW	SE	N	NW	NW	NW	NW
1881-1890	NW	NW	NW	NW	SE	S	S	N	N	NW	NW	NW	NW
1891-1900	W	W	NW	NW	SE	SW	SW	NW	SE	NW	NW	NW	NW
1871-1902	NW	NW	NW	NW	SE	SW	SW	SW	N	NW	NW	NW	NW

January, 1871-October, 1879, from eye observations at 7.30 a. m., 4.30 p. m., and 11.00 p. m.
November, 1879-December, 1886, " " " " 7.00 " 3.00 " " 11.00 "
January, 1887-June, 1888, " " " " 7.00 " 3.00 " " 10.00 "
July, 1888-November, 1892, " " " " 8.00 " and 8.00 p. m.
December, 1892-December, 1903, " hourly record.

spring, the south winds; in the summer, the southwest; in autumn, the winds from any quarter between east and southwest have about the same temperature. The relative position of the winds, arranged according to temperature, with the warmest first, is indicated below:

RELATIVE TEMPERATURE OF THE WINDS.

	Warmest.							Coldest
January	SE	E	SW	NE	W	S	NW	N
April	S	SW	SE	W	N	E	NE	NW
July	SW	S	W	SE	NW	NE	E	N
October	SE	S	SW	E	NE	NW	W	N
Year	SE	SW	S	E	W	NE	NW	N

COMPARATIVE PREVALENCE OF STATED DIRECTIONS.
(In average number of hours and minutes per day.)

	N	NE	E	SE	S	SW	W	NW
January	2.54	1.42	3.06	2.36	0.30	3.06	5.30	4.36
April	1.24	1.54	2.24	7.24	0.30	3.24	3.24	3.36
July	2.36	0.42	1.12	3.18	2.12	7.12	3.24	3.24
October	4.18	1.42	2.36	3.24	1.24	3.06	2.54	4.36
Average	2.54	1.24	2.24	4.06	1.12	4.06	3.48	4.06

In the above table the figures show the number of hours and minutes during which the stated winds prevailed during the five years from 1893 to 1897. For example, in January a north wind prevailed on the average for the five years, during 12 per cent of each day, or a little less than three hours. This is equivalent to about 3.7 days for the entire month. A south wind is in all months of the year of decidedly shortest duration and of least frequency.

Monthly Frequency of Stated Directions.

A four years' record of hourly wind directions was examined and the observations tabulated in such manner as to show the number of days per month upon which the wind blew from each quarter. The monthly number of days for the entire year is as follows:

	N	NE	E	SE	S	SW	W	NW
Average no. of days	19.0	16.0	15.9	16.4	15.8	18.7	19.7	20.5
Highest number	21.8	19.5	19.2	22.0	19.5	23.8	22.8	22.2
Lowest number	16.2	14.0	14.0	9.5	9.2	11.0	16.5	15.8

The above figures indicate that the wind blows from nearly every quarter once in about two days. Take for example a northwest wind; on the average it blows on 20.5 days per month the year round; in January, February, March and July it has an average frequency of 22.2 days, and in September 15.8 days. We may also learn from these figures that the wind blows from four to five different directions every day, on the average. The exact figures, based on the four years' record, are as follows for each month of the year:

AVERAGE DAILY NUMBER OF WIND DIRECTIONS.

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
4.6	4.3	4.4	4.8	4.8	5.2	4.9	5.3	4.6	4.1	4.4	4.6	4.7

These figures are in harmony with the facts recorded in the discussion of the diurnal periodicity of wind direction. It was there shown that the wind backed daily from a westerly direction in the morning to southeast or east in the afternoon, and then returned again at night to the west or northwest; in other words, that the wind shifted through four or five points by noon and returned to its original position at night.

The Direction of Upper and Lower Clouds.

Table LXXVI is inserted at this point simply to show the prevailing direction of the wind at the level of the upper and lower clouds. The observations cover a period of five years and indicate the directions at 7 a. m. and 3 p. m. The upper clouds include all cirrus forms, the alto-stratus and alto-cumulus; the lower forms include the cumulus and stratus forms.

The upper clouds move from the west throughout the year, both in the morning and afternoon, with an occasional exception in the way of a northwest or southwest direction, especially at the afternoon observation. The lower clouds are also mostly from the west at 7 a. m. from May to December; from January to April they are generally northwest. In the

TABLE LXXVI.—PREVAILING DIRECTION OF LOWER AND UPPER CLOUDS.

		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
1883	*7 a. m.*	....	....	....	....	....	....	*W*	*W*	*W*	*W*	*W*	*W*	*W*
	3 p. m.	....	....	....	....	....	....	*W*	*W*	*W*	*SW*	*W*	*W*	*W*
	7 a. m.	....	....	....	....	....	....	W	W	W	W	SW	N	W
	3 p. m.	....	....	..	....	...	..	W	W	W	W	W	N	W
1884	*7 a. m.*	....	....	*NW*	*NW*	*W*	*NW*	*W*	*W*	*W*	*W*	*N*	*W*	*W*
	3 p. m.	*W*	*S*	*W*	*NW*	*W*	*W* *E*	*W*	*W*	*W*	*W*	*W* *NW*	*W*	*W*
	7 a. m.	N	NE	NW	NW	W	NE SE	W	W	W	W	NW	W	W
	3 p. m.	S	S SW	W	NW	NW	E	W	W	NW	NW	NW	NW	NW
1885	*7 a. m.*	*W*	*NE*	*W*	*W*	*SW* *NW*	*W*	*W* *NW*	*SW* *W*	*W*	*SW*	*W*	*NW*	*W*
	3 p. m.	*W*	*W*	*W*	*NW*	*SW* *W*	*W*	*W*	*W*	*W*	*W*	*NW*	*W*	*W*
	7 a. m.	SW W	N	W	W	E	NW	W	W	W	SW	W	W NW	W
	3 p. m.	W	NW	W	SW NW	NW	NW	NW	SW	W	SW	NW	NW	NW
1886	*7 a. m.*	*W*	*SW*	....	*SW* *NW*	*W*	*W*	*NW*	*NW*	*W*	*SW* *NW*	*W*	*W*	*W*
	3 p. m.	*W*	*SW*	*NW*	*NW*	*NW*	*W*	*NW*	*W*	*SW* *NW*	*W*	*W*	*W*	*W*
	7 a. m.	W NW	NW	NW	NE NW	NE W	W	W	W	NE	N	W	SW NW	W
	3 p. m.	SW W	NW	W	NW	NW	NW	NW	SW W	W	NW	NW	W	NW
1887	*7 a. m.*	*W*	*W*	*W*	*W*	*W*	*W*	*W*	*W*	*W*	*W*	*W*	*W*	*W*
	3 p. m.	*W*	*W*	*W*	*N* *W*	*W*	*W*	*W*	*W*	*W*	*W*	*W*	*W*	*W*
	7 a. m.	SW	SE SW	NW	NE NW	S	NE W	SW	NE S	SW	W	W SW	W	SW
	3 p. m.	NW	NE NW	NW	SE NW	E	W	SW NW	N	SE	NW	NW	NW	NW
1888	*7 a. m.*	*W*	*W*	*NW*	*W*	*W*	*W*	....	....	....	....	....	....	*W*
	3 p. m.	*W*	*W*	*W*	*W*	*W*	*W*	....	....	....	....	....	....	*W*
	7 a. m.	NW	W	W	W	SW	SW	....	....	....	....	....	....	W
	3 p. m.	W	W	NW	NW	SW	W	....	....	....	....	....	....	W
Prevail.	*7 a. m.*	*W*	*W*	*W*	*W*	*W*	*W*	*W*	*W*	*W*	*W*	*W*	*W*	*W*
	3 p. m.	*W*	*W*	*W*	*NW*	*W*	*W*	*W*	*W*	*W*	*W*	*W*	*W*	*W*
	7 a. m.	SW NW	NE	NW	NW	W	W	W	W	W	W	W	W	W
	3 p. m.	W	NW	W	NW	NW	W NW	NW	W	W	NW	NW	NW	NW

Upper clouds. { *Ci.*, *Ci. S.*, *Ci. Cu.*, *A. Cu.*, *A. S.* } *in Italic.*   Lower clouds. { Cu., S. Cu., S., N. } in Roman.

afternoon, a northwest direction prevails during eight months of the year in the lower cloud layer, with a direction from the west in January, March, August and September.

ELECTRICAL PHENOMENA.

Thunderstorms.

The intimate relation existing between thunderstorm formation and temperature is demonstrated by an inspection of Table LXXVII and Fig. 77. The maximum frequency occurs in the month of greatest heat

TABLE LXXVII.—HOURLY FREQUENCY OF THUNDERSTORMS.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
Midn't to 1 a. m.	..	..	2	..	1	..	2	1	1	..	..	..	7
1- 2	..	..	..	..	..	..	..	1	..	..	..	..	1
2- 3	..	..	2	..	..	..	1	..	..	..	..	..	3
3- 4	..	..	..	..	..	6	..	..	1	..	..	..	7
4- 5	..	..	..	..	..	..	..	..	..	..	..	..	0
5- 6	..	..	..	..	..	..	1	1	1	..	..	..	3
6- 7	..	1	..	..	1	4	..	..	..	..	..	..	6
7- 8	..	..	2	..	2	..	1	..	..	1	..	..	6
8- 9	..	1	..	..	..	1	1	2	1	..	..	..	6
9-10	..	..	1	3	..	..	2	2	..	..	..	..	8
10-11	..	1	..	..	1	2	3	..	..	1	..	1	9
11-Noon	..	..	..	..	1	3	4	6	..	..	1	..	15
Noon - 1 p. m.	..	1	1	1	2	6	8	2	..	..	..	1	22
1- 2	..	..	2	..	5	13	16	6	4	..	..	..	46
2- 3	..	..	1	5	15	16	21	12	5	1	..	..	76
3- 4	1	1	2	2	9	22	22	15	4	..	..	..	78
4- 5	..	..	..	2	12	16	20	5	6	..	..	..	61
5- 6	..	..	1	3	8	12	18	10	2	1	..	..	55
6- 7	1	..	1	3	17	14	14	13	3	2	1	..	69
7- 8	1	..	2	1	5	8	9	6	4	..	2	..	38
8- 9	..	1	1	1	5	7	8	7	3	1	..	..	34
9-10	..	2	..	2	8	6	7	5	1	..	..	..	31
10-11	..	1	..	1	1	4	3	2	2	..	2	..	16
11-Midn't	..	..	1	..	4	1	3	4	..	..	..	..	13
Totals	3	9	19	24	97	141	164	100	38	7	6	2	610

Table LXXVII shows the total number of thunderstorms recorded as beginning within the stated hours in the 27 years from 1876 to 1903, during each month and during the entire year.

and at the hour of the daily maximum temperature. In tabulating all thunderstorms which passed over Baltimore during a period of 28 years, a total of 678, we find the following distribution by months:

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
13	11	20	33	107	156	179	111	43	7	6	2	678

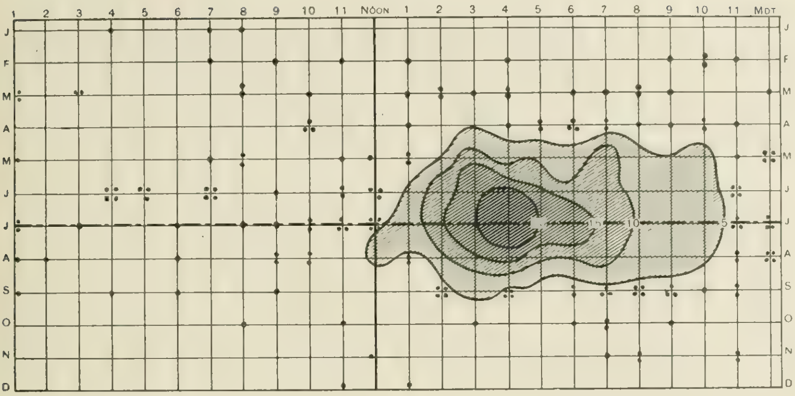


FIG. 77.—The Frequency and Distribution of Thunderstorms.

The diagram represents over 650 thunderstorms which passed over Baltimore in the 30 years from 1871 to 1900. The density of the shading increases with the frequency of the storms, showing a maximum frequency between 3 p. m. and 5 p. m. in the month of July. For the hours of the day and month during which less than five storms were recorded in 30 years, the actual number is indicated by the small dots. The figures attached to the curved lines represent the total frequency in 30 years.

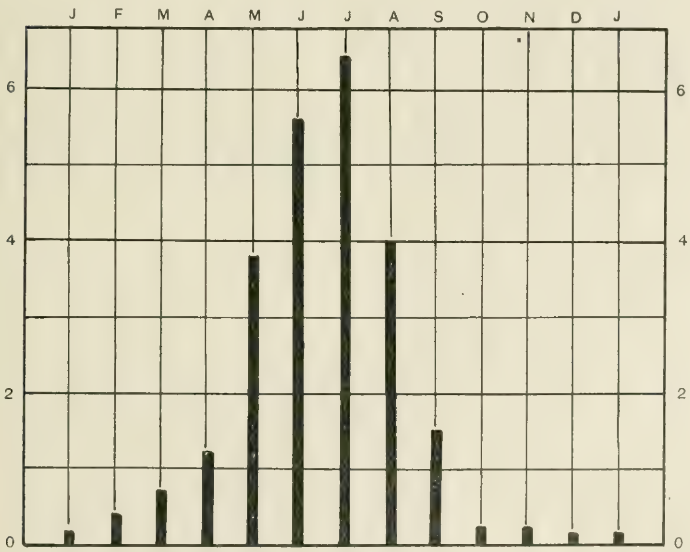


FIG. 78.—The Average Monthly Frequency of Occurrence of Thunderstorms.

About five-sixths of the total annual number occur in the months of May, June, July and August. In the winter months they occur only at rare intervals, generally in connection with cyclonic storms which exhibit strong contrasts in temperature. The summer storms occur mostly in connection with shallow and not very well defined cyclonic depres-

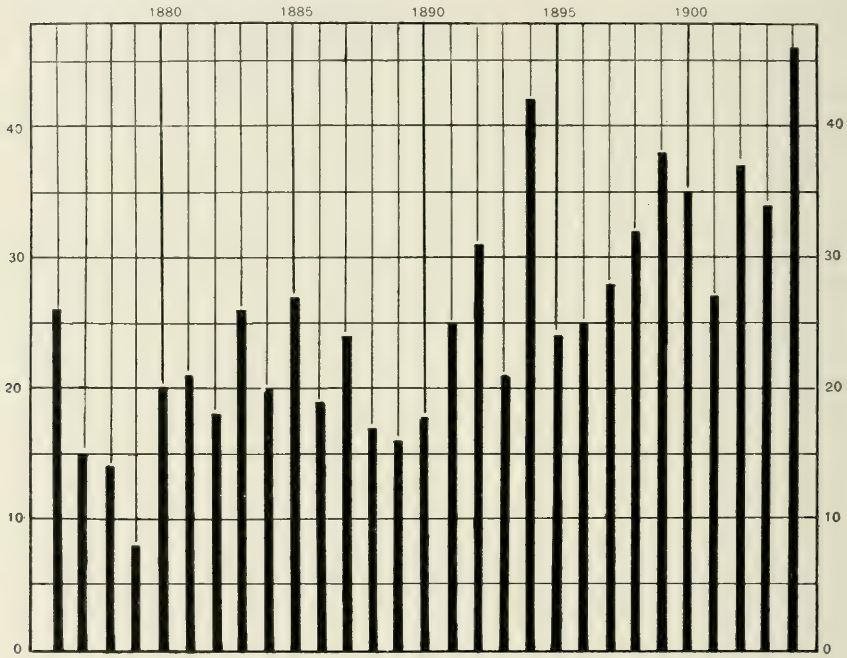


Fig. 79.—The Annual Frequency of Occurrence of Thunderstorms from 1871 to 1904.

sions. That there is a strongly marked diurnal periodicity in the formation of the summer thunderstorms is shown by the following figures:

HOURLY FREQUENCY OF THUNDERSTORMS.

Hours ending	1	2	3	4	5	6	7	8	9	10	11	12
Morning	7	1	3	7	0	3	6	6	6	8	9	15
Afternoon	22	46	76	78	61	55	69	38	34	31	16	13

The hourly distribution for all months, expressed in terms of the total frequency in 30 years, is shown in Fig. 77. The monthly and annual distribution by years, from 1876 to 1903, is shown in Table LXXVIII. The annual changes in frequency are also shown graphically

TABLE LXXVIII.—NUMBER OF THUNDERSTORMS PER MONTH.

Year.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
1876	..	..	1	..	5	7	7	5	1	..	..	..	26
1877	..	..	..	1	3	3	5	1	1	..	1	..	15
1878	..	..	2	2	3	1	4	2	..	..	..	..	14
1879	..	..	..	..	..	2	4	1	1	..	..	..	8
1880	1	..	..	3	1	8	4	3	..	..	..	..	20
1881	..	..	2	1	3	6	3	4	2	..	..	..	21
1882	..	1	..	1	1	4	6	3	2	..	..	..	18
1883	..	..	..	1	2	6	15	1	1	..	..	..	26
1884	..	1	1	..	5	3	6	3	..	..	1	..	20
1885	..	1	..	1	3	5	5	10	1	1	..	..	27
1886	..	..	..	1	6	2	5	2	3	..	..	..	19
1887	..	1	..	..	5	8	7	3	..	..	..	..	24
1888	..	..	1	1	2	5	1	5	..	2	..	..	17
1889	..	..	..	2	3	6	4	1	..	..	..	..	16
1890	..	1	..	2	3	3	3	5	1	..	..	..	18
1891	..	..	..	2	3	8	5	3	1	1	1	1	25
1892	..	..	..	1	8	11	7	4	..	..	..	..	31
1893	..	1	1	..	5	7	5	..	2	..	..	..	21
1894	..	..	4	6	8	8	7	2	5	1	..	1	42
1895	..	..	..	..	..	8	6	8	2	..	..	..	24
1896	..	..	..	..	6	6	7	4	2	..	..	..	25
1897	..	1	..	1	3	6	7	7	1	2	..	..	28
1898	1	..	..	1	8	4	8	9	1	..	..	..	32
1899	1	1	4	2	6	5	11	5	3	..	..	..	38
1900	..	..	..	..	1	5	8	6	3	..	2	..	25
1901	..	..	2	..	3	2	10	5	5	..	..	..	27
1902	..	2	1	2	4	8	11	6	2	..	1	..	37
1903	..	1	1	2	7	9	8	3	3	..	..	..	34
Totals, 1876-1903	3	11	20	33	107	156	179	111	43	7	6	2	678
Average	0.1	0.4	0.7	1.2	3.8	5.6	6.4	4.0	1.5	0.2	0.2	0.1	24.2

in Fig. 79. The average annual number is approximately 24, with a maximum frequency of 42 in 1894, and a minimum of 8 in 1879. The following figures express more exactly the average monthly and annual frequency (See also Fig. 78):

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
0.1	0.4	0.7	1.2	3.8	5.6	6.4	4.0	1.5	0.2	0.2	0.1	24.2

Thunderstorm Probability.

The probability of the occurrence of a thunderstorm upon any designated day may be expressed in a very rough way by finding how many times a storm occurred on that day in the past. By examining all records of thunderstorms for 27 years and arranging them according to the day of the month upon which they occurred, we may roughly obtain a percentage of probable occurrence.

Not much reliance should be placed upon such a method of forecasting, but some interesting relative values are brought out. In the past 27 years one or more thunderstorms have occurred on every day of May, June and July, and on all but one day in August (the 20th); no thunderstorm has occurred on September 6, 13, 21 to 23, 27, 28 or 30. In April there is no record of a storm on the following days: 1, 3, 6, 7, 13 to 15, 21 to 23, 25, 30. The highest number occurring on any stated day in May is 7, on the 21st; in June, 11 on the 21st; in July, 11 on the 5th; in August, 7 on the 12th. Hence the highest probability of occurrence upon any day in the year is only eleven twenty-sevenths, or about 41 per cent. The average probability for a day in May is 14 per cent; in June, 20 per cent; in July, 23 per cent; in August, 15 per cent. The probability for the Fourth of July is only 17 per cent, or 5 per cent less than the average for July days. According to the Baltimore records a thunderstorm has passed over the city on July 4 only five times in 29 years. One has occurred 11 times on July 5, in the same period, making the maximum probability 41 per cent of the total number of such days in 29 years.

Consecutive Days with Thunderstorms.

Thunderstorms generally occur as isolated storms in the vicinity of Baltimore. In over 80 per cent of all instances, a second storm does not occur on the following day. In only 14 per cent of all cases have there been thunderstorms recorded on two successive days, and in only a little over three per cent have storms occurred on three successive days. Only on one occasion have as many as 5 occurred on 5 successive days. These percentages vary in different months but they are not

large in any month. The following table shows the figures for each month and for the year:

CONSECUTIVE DAYS WITH THUNDERSTORMS.
(Total number in 28 years.)

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Single storms	3	11	16	26	65	87	94	67	26	7	6	2	410
On 2 consecutive days	..	..	..	2	13	18	21	12	6	..	..	..	72
" 3 " "	..	..	1	0	2	4	5	4	1	..	..	..	17
" 4 " "	..	..	..	..	..	1	3	..	..	..	..	..	4
" 5 " "	..	..	..	..	..	1	..	..	..	..	..	..	1

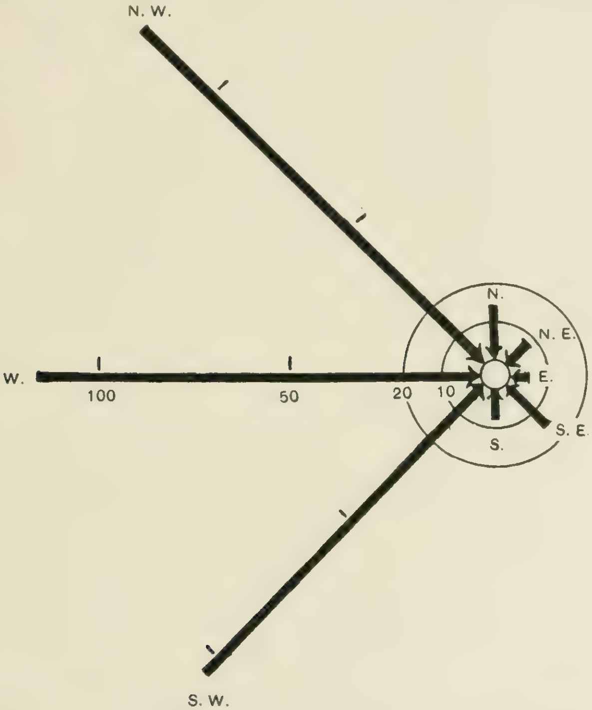


FIG. 80.—The Direction of Movement of Thunderstorms.

The diagram shows the actual and relative frequency of thunderstorms from each direction of the compass. The total number of storms represented is nearly 400.

DIRECTION OF THUNDERSTORMS.

In the vicinity of Baltimore, thunderstorms usually come into view from some point between northwest and southwest. Out of a total of

about 400 storms, nearly 90 per cent moved from some one of these points. (See Fig. 80.) The order of frequency of direction is as follows:

THUNDERSTORM DIRECTIONS.
(1876-1902.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
NW to SE	1	..	3	8	26	20	33	21	18	1	..	..	126
W " E	..	..	3	7	19	29	32	18	5	2	..	..	115
SW " NE	1	2	4	3	12	31	20	21	7	2	1	..	104
S " N	..	..	..	1	2	..	2	3	..	..	..	..	8
SE " NW	..	..	..	..	2	3	6	2	..	..	..	1	14
E " W	..	..	..	..	..	1	..	2	1	..	..	..	4
NE " SW	..	..	..	..	..	2	5	..	..	..	..	..	7
N " S	..	..	1	..	2	5	2	2	1	..	..	..	13

Pressure Changes During Thunderstorms.

A thunderstorm usually occurs with a falling barometer; the barometer rises during the first few minutes after the storm has begun, falls slightly before the close of the first hour, and then maintains a steady pressure for several hours, eventually rising slowly (see Fig. 81). In other words, the storm usually breaks in the trough of a cyclonic disturbance. The following table shows the average hourly barograph

PRESSURE BEFORE AND AFTER THUNDERSTORMS.
(Station readings; not reduced to sea-level.)

		Hours Preceding.					Rise.			Hours following.				
Month.	No.	5th	4th	3rd	2nd	1st	Beginning.	Time.*	Maximum.	1st	2nd	3rd	4th	5th
Feb....	(2)	29.45	.42	.40	.36	.34	29.31	0.25	29.36	.34	.30	.26	.20	.18
March.	(3)	.67	.63	.60	.56	.51	.49	0.25	.53	.51	.51	.51	.52	.54
April..	(2)	.38	.38	.38	.38	.38	.38	1.18	.47	.44	.44	.42	.44	.44
May...	(18)	.78	.77	.76	.75	.74	.74	0.42	.79	.77	.77	.78	.79	.80
June...	(16)	.79	.78	.77	.76	.75	.74	0.42	.77	.75	.74	.74	.75	.75
July...	(19)	.77	.77	.75	.74	.73	.72	0.51	.78	.74	.74	.74	.74	.76
Aug...	(11)	.80	.80	.79	.79	.79	.79	0·40	.84	.81	.80	.79	.79	.80
Sept...	(5)	.76	.75	.74	.73	.72	.70	0.53	.75	.74	.75	.77	.78	.80
Aver...	(76)	.68	.66	.65	.63	.62	.61	.45	.66	.64	.63	.63	.63	.63

* Time from beginning of the rise to its maximum, in hours and minutes.

readings before and after about 75 thunderstorms selected from the records of the past three or four years. The readings of the barograph

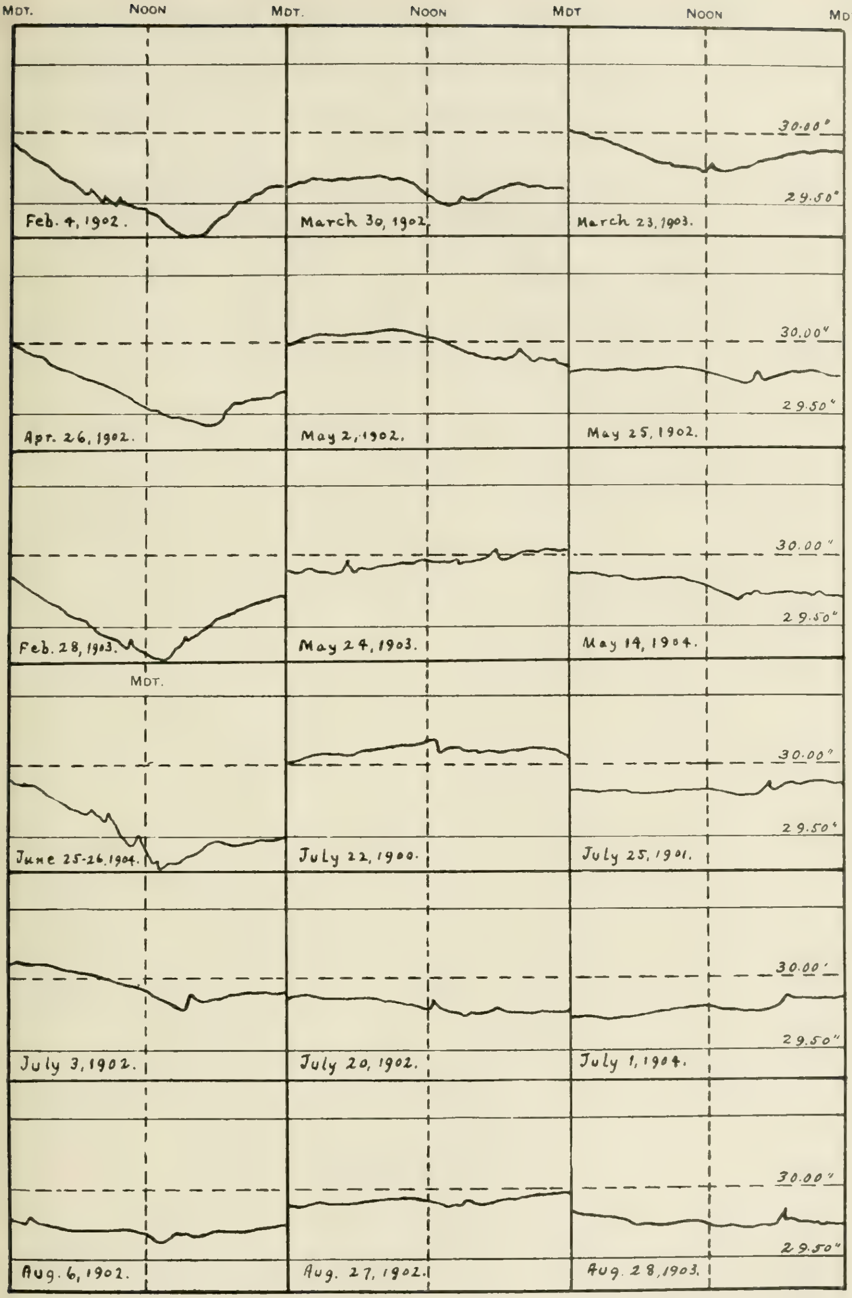


FIG. 81.—Some Typical Barograms During Thunderstorms and Squalls.

are given for the five hours preceding and following the breaking out of the storm. The minimum reading is also given, just before the beginning of the "hump," which constitutes the characteristic feature of a barograph curve during the passage of a thunderstorm. The duration of the rise in pressure, from the minimum to the maximum point attained in the "hump" is given in hours and minutes.

Of the 76 thunderstorms examined in the above table, about one-third began with a value between 29.60 inches and 29.69 inches for the barometer reading, assuming the beginning of the rise in the barometer to be the beginning of the storm. Tabulating the barometer readings according to the pressure at the breaking out of the storm, we have the following comparative frequency of stated values:

FREQUENCY OF STATED READINGS OF THE BAROMETER AT THE BEGINNING OF THE STORM.

Barometer Reading.	Frequency Actual.	Frequency Percentage.
29.30-39 inches	3	4
40-49 "	5	7
50-59 "	5	7
60-69 "	24	32
70-79 "	14	18
80-89 "	17	22
90-99 "	7	9
30.00-09 "	1	1
	76	100

The thunderstorms in the above table were confined almost entirely to the months of May to August. We see that the storm broke most frequently when the pressure registered some value between 29.60 inches and 29.69 inches; this was true of 32 per cent of all cases tabulated; in 72 per cent of all cases the barometer reading was between 29.60 inches and 29.89 inches. In only one instance was the pressure above 30.00 inches, namely, in July, 1900. The lowest pressure recorded in any case was 29.30 inches, in February, 1903. See Fig. 81 for the character of the rise in pressure during thunderstorms.

Hail.

The phenomenon of hail formation is so intimately associated with the dynamics of thunderstorms that the treatment of the subject is taken

up in connection with these storms rather than with the subject of precipitation. Hail is not of frequent occurrence in the vicinity of Baltimore. During a period of 28 years it has been recorded but 49 times, or less than two times per year. The annual number has varied between 0 and a maximum of 6. The monthly and annual distribution is shown in Table LXXIX, and the hourly distribution by months in Fig. 82.

TABLE LXXIX.—FREQUENCY OF OCCURRENCE OF HAIL.

Year.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1876	..	..	1	..	2	..	..	..	..	..	..	..	3
1877	2	1	..	..	..	..	..	..	..	..	..	..	3
1878	..	..	..	..	..	..	..	..	..	..	..	..	0
1879	..	..	..	..	..	2	..	..	..	..	..	..	2
1880	..	..	..	1	..	..	1	..	..	..	..	..	2
1881	..	..	..	..	..	1	..	..	..	..	..	..	1
1882	..	..	..	..	..	1	..	..	..	..	..	..	1
1883	..	..	..	..	..	..	..	..	..	..	..	..	0
1884	..	..	..	..	..	..	1	..	..	..	..	..	1
1885	..	..	..	..	..	..	..	..	..	..	..	..	0
1886	..	..	..	..	..	..	..	..	..	..	..	..	0
1887	..	1	..	..	1	1	1	..	..	..	..	..	4
1888	..	..	..	..	..	2	..	1	..	..	..	..	3
1889	..	..	..	..	..	..	..	..	..	..	..	..	0
1890	..	..	..	1	1	1	..	..	..	..	..	..	3
1891	..	..	..	..	..	..	..	..	..	..	..	..	0
1892	..	..	..	..	1	1	..	..	..	..	..	..	2
1893	..	..	..	..	..	..	2	..	..	..	..	..	2
1894	.	..	..	..	1	2	..	..	..	..	..	..	3
1895	1	..	..	..	..	..	2	2	1	..	..	..	6
1896	..	..	..	..	..	..	1	..	..	..	..	..	1
1897	..	..	..	..	1	..	..	1	..	..	..	..	2
1898	..	..	..	..	1	..	..	..	..	..	..	1	2
1899	..	..	2	1	1	1	..	1	..	..	1	..	7
1900	1	..	..	..	..	..	..	..	..	..	..	..	1
1901	..	..	..	..	1	..	1	..	..	..	..	..	2
1902	..	1	..	..	..	..	..	1	..	..	..	..	2
1903	..	..	..	..	1	1	..	..	..	..	..	..	2
Total in 28 years....	4	3	3	3	11	13	9	6	1	0	1	1	55

The hourly distribution for the entire year is as follows:

HOURLY FREQUENCY OF HAIL.

(Total number in 28 years.)

Time A. M.	9	10	11	Noon.	1	2	3	4	5	6	7	8	9	10	11	P. M.
Frequency.	2	1	1	2	3	0	4	6	13	7	4	3	2	0	1	..

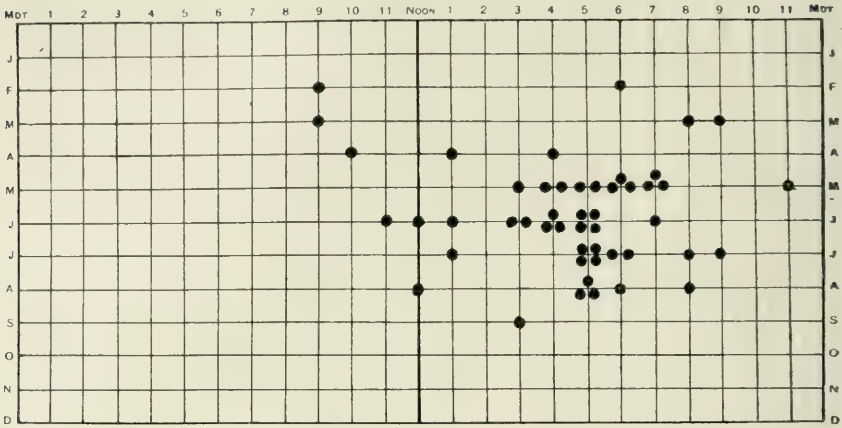


FIG. 82.—The Frequency of Occurrence and the Hourly and Seasonal Distribution of Hailstorms.

The diagram shows all of the hailstorms recorded as occurring in Baltimore during a period of 28 years. Each black dot represents a storm.

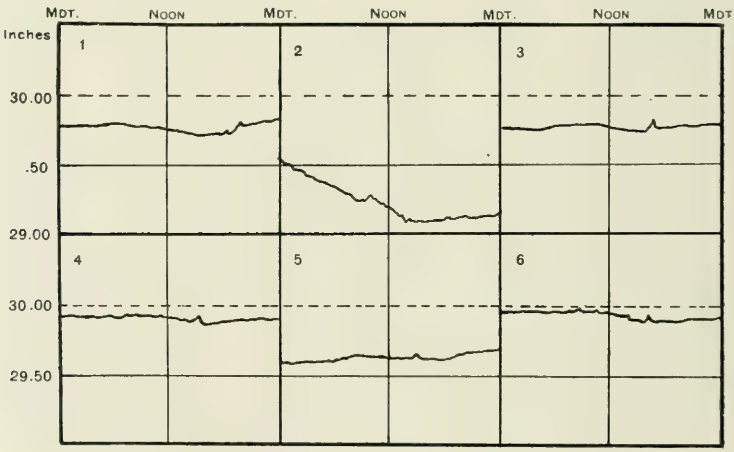


FIG. 83.—Barograms During Hailstorms.

Each barogram represents a period of 24 hours, from midnight to midnight. The time of occurrence of the hail-storm is indicated by the sharp temporary rise and fall in the curve.

Dates of the storms represented: 1. July 7, 1901. 2. February 28, 1902. 3. August 27, 1902. 4. June 8, 1903. 5. May 19, 1904. 6. July 5, 1904.

The hourly frequency rises to a maximum between 4 p. m. and 5 p. m. The dates of all recorded occurrences of hail in the vicinity of the Baltimore station of the Weather Bureau are given in Table LXXX.

TABLE LXXX.—DATE AND HOUR OF OCCURRENCE OF HAIL.

Date	Time	First precip.*
1876, Mar. 28	7.15 p. m.	....
" May 12	2.15 p. m.– 2.30 p. m.	....
" " 21	....	9.35p
1879, June 11	2.55 p. m.– 3.03 p. m.	....
" " 28	†	4.29p
1880, Apr. 17	Early a. m.	....
" July 20	†	4.40p
1881, June 8	....	3.15p
1882, " 19	†	Noon.
1884, July 11	4.00 p. m.– 4.50 p. m.	....
1887, Feb. 18	5.02 p. m.– 5.05 p. m.	....
" May 26	†	5.20p
" June 18	†	4.35p
" July 18	....	5.10p
1888, June 16	2.30 p. m.– 2.35 p. m.	....
" " 23	†	11.08a
" Aug. 8	5.45 p. m.– 5.50 p. m.	....
1890, Apr. 27	3.45 p. m.– 4.00 p. m.	....
" May 14	†	6.55p
" June 12	....	3.55p
1892, May 23	‡ 4.08 p. m.– 4.10 p. m.	....
" June 30	12.02 p. m.–12.10 p. m.	....
1893, July 3	5.25 p. m.– 5.35 p. m.	....
" " 8	†	4.10p
1894, May 6	6.57 p. m.– 7.03 p. m.	....
" June 12	4.37 p. m.– 4.40 p. m.	....
" " 24	†	4.10p

Date	Time	First precip.
1895, July 5	12.25 p. m.–12.30 p. m.	....
" " 16	†	4.30p
" Aug. 11	4.50 p. m.– 4.52 p. m.	....
" " 31	4.30 p. m.– 4.35 p. m.	....
" Sept. 19	†	3.10p
1896, July 27	8.13 p. m.– 8.17 p. m.	....
1897, May 21	1.45 p. m.– 1.55 p. m.	....
" Aug. 23	11.47 a. m.–11.52 a. m	
1898, May 16	4.10 p. m.– 4.13 p. m. 5.14 p. m.– 5.17 p. m.	....
1899, Mar. 12	‡ 8.27 p. m.– 8.35 p. m.	....
" " 28	8.07 a. m.– 8.09 a. m.	...
" Apr. 16	10.25 a. m.– .... 12.20 p. m.–	....
" May 16	†	6.50p
" June 6	†	7.22p
" Aug. 21	7.33 p. m.– 7.38 p. m.	....
1901, May 25	†	10.15p
" July 7	7.00 p. m.	...
1902, Feb. 28	9.50 a. m.	....
" Aug. 27	4.43 p. m.– 5.05 p. m.	....
1903, May 24	3.24 p. m.– 3.27 p. m.	.
" June 8	3.27 p. m.– 3.33 p. m.	....

*** In the absence of the exact time of occurrence of hail the time of beginning of precipitation is given.**

† Hail in city or suburbs; none at station.

‡ Not accompanied by a thunderstorm.

In Fig. 83 a few typical barograms are reproduced showing the characteristically sharp rise and fall of the atmospheric pressure during the passage of a hailstorm. In the thunderstorm curve the summit of the "hump" is usually more rounded, as shown in Fig. 81.

Auroras.

The following brief list contains all occurrences of the aurora borealis reported in the records of the U. S. Weather Bureau at Baltimore since the establishment of the station in 1871:

Date.	Duration.	Date.	Duration.
1872, Feb. 3	8 p. m. to 9 p. m.	1892, Feb. 13	6.30 p. m. to 9 p. m.
Apr. 11	8 p. m. " 10 p. m.	May 18	8 p. m. " 11 p. m.
Aug. 3	8.40 p. m. " 10 p. m.	July 16	10.30 p. m. " 11.30 p. m.
Aug. 4	About 9 p. m.	1893, Feb. 4	9 p. m. " 12 md't.
Aug. 8-9	9 p. m. to 2 a. m.	1894, Feb. 23	9 p. m. " 10 p. m.
Oct. 14	6.30 p. m. " 7 p. m.	Mar. 30	7.20 p. m. " early a. m.
Nov. 1	10 p. m. " 11 p. m.	1897, Jan. 23	Evening.
1873, June 26	About 10 p. m.	1898, Sept. 2	About 10 p. m.
1882, Apr. 16-17	10 p. m. to 3 a. m.	1903, Oct. 12	7 p. m. to 7.30 p. m.
Apr. 20	12.30 a. m. to 3 a. m.		

Sunspots and Weather.

The effort to extend the period covered by weather forecasts has ever been one of the chief aims of the practical meteorologist. The limit of time for which forecasts are now issued by American and European official weather services is about three days. The forecasts made from day to day generally cover from 24 to 48 hours; under favorable conditions the time is occasionally extended to three, or even four days, but this is only done in exceptional cases. The three or four day limit is probably the utmost that will be realized from present methods, and with the material now at our disposal. The only hope of extending the period lies in the discovery of some new laws of weather sequences.

The search for periodical recurrences of similar weather conditions has long been one of the most interesting, and, at the same time, one of the most elusive problems in cosmical physics. The investigations have usually been along two lines: A series of observations has been subjected to close examination and critical analysis in order to discover any periodic change which may be hidden in the constant fluctuation of values; or a periodic movement has been assumed and the weather observations examined for synchronous changes.

There is but one undisputed source of terrestrial weather changes—namely, the sun. While no one doubts the influence of the sun upon

the earth's atmosphere many claims have been, and are still being made in favor of attributing to other heavenly bodies, such as the moon or the planets, a considerable effect. The champions of the moon's influence are legion, and they never grow less; but the arguments of several centuries, including much serious and intelligent effort, have not succeeded in securing for lunar or planetary forecasts a position more exalted than the pages of the perennial almanac.

It is now approximately 100 years since a definite period was discovered in the increase and decrease of sunspot frequency, and less than 50 years since the flames emanating from the surface of the sun, or the solar prominences, were first observed. The first definite relation between sunspot frequency and terrestrial changes was the discovery of the synchronous activity of the magnetic needle. There is now no question about the coincidence of these phenomena whatever may be the true relation existing between them.

In attributing terrestrial changes of the weather to "sunshine," we have until comparatively recent times assumed a constant output of radiant energy from the sun. In view of the fact that our present knowledge concerning the physical condition of the sun indicates a surrounding atmosphere composed of incandescent metallic vapors, is it not more rational to suppose that the temperature of these highly heated gases is varying constantly, than it is to think of them as at a constant temperature? If the temperature does vary, the fluctuations must necessarily affect to a greater or less degree the physical condition of our own atmosphere. The question then becomes one of degree of influence. There are many observed facts which point to a varying output of solar radiant energy, and quantitative measurements will not long remain unknown. Just what the nature of this influence is has certainly not yet been demonstrated. One obstacle in the way of more rapid progress toward a solution of these problems may be found in the crudeness of much of our observational data, and the lack of uniformity in the methods and hours of observation. Moreover, in the middle latitudes where most of our best observations, and the longest series which we possess, have been made, the non-periodic fluctuations are so much

greater than the periodic changes sought that the latter are separated out from the former only with the greatest difficulty and care. The most favorable regions of investigation for periodicities based on solar changes are the tropics. Here the daily, seasonal, and incidental changes in weather conditions are more uniform and less pronounced, permitting of more ready detection of the periodic changes of longer duration.

It seems highly probable that changes in terrestrial temperature, in rainfall, storm frequency, etc., may be due to changes in the physical constitution of the sun's surface. It may also be that these solar changes are not reflected directly in the conditions above mentioned. Similar weather conditions should not be expected in all parts of the earth at the same time. The results of efforts thus far to find a direct connection between the sunspots and weather changes have apparently failed largely as a consequence of dissimilar weather conditions found in different localities during similar phases of the solar period. These contradictions may be only apparent, not real. Let us suppose, for instance, that the normal distribution of pressure over large areas is disturbed as a result of changes in the quantity of heat received from the sun from year to year. We would then have excessive heat in some places and at the same time abnormal cold at others; or we would have excessive rains here and droughts there; or an increase in storm frequency in one place and a decrease in another, when compared with average conditions. Such variations cannot be looked upon as contradictory; they are the natural results of changes in the distribution of pressure, changes such as we see upon our weather charts every day.

The present status of the problems concerning the relation between the varying physical conditions of the sun and synchronous changes in our terrestrial atmosphere is well stated in the following extract from a recent paper by Professor Bigelow,* who is one of the most active and able investigators in this most promising field of cosmical physics.

"The numerous studies during the past fifty years into the apparent

*Bigelow, F. H. Synchronism of the Variations of the Solar Prominences with the Terrestrial Barometric Pressures and the Temperatures. Monthly Weather Review, Washington, D. C., November, 1903.

synchronism between the solar variations of energy and the terrestrial effects, as shown in the magnetic field and the meteorological elements, have been on the whole unsatisfactory, if not disappointing. Just enough simultaneous variation has been detected in the atmospheres of the sun and the earth to fascinate the attentive student, if not to justify a large expenditure of labor, in view of the great practical advantages to be obtained in the future as the result of a complete understanding of this cosmical pulsation. The attack upon the problems has really consisted in rather blindly groping for the most sensitive pulse in the entire cosmical circulation, and in disentangling the several interacting types of impulses. It is evident that the partial failures hitherto attending this work have been due to two principal causes: (1) The comparison was made between the changes in the spotted areas of the sun and the terrestrial variations, but these solar changes were not sensitive enough to register a complete account of the action of the solar output. Discussions of the spots are being replaced by others upon the solar prominences and faculæ, which respond much more exactly to the working of the sun's internal circulation: (2) The magnetic and meteorological observations have not been handled with sufficient precision to do justice to the terrestrial side of the comparison. It is evident that all these physical data at the sun and at the earth must be computed with an exactness comparable to that of astronomical observations of position, if meteorology is to be raised to the rank of a cosmical science. When one considers the crudeness of the meteorological data, taken the world over, due to the character of the instruments employed, the different local hours of observation, and the divergent methods of reduction, it is no wonder that small solar variations have been swallowed up in the bad workmanship of meteorologists. The prevailing methods have been sufficient for forecasting and for climatological purposes, but they are entirely inadequate for the cosmical problems whose solution will form the basis of scientific long-range forecasts over large areas of the earth—that is, for forecasting the seasonal changes of the weather from year to year. It is perfectly evident that if secular variations of any kind, such as the annual changes in terrestrial pressure,

temperature, or magnetic field, are to be attributed to solar action, the original observations must be finally reduced to a homogeneous system. The local peculiarities of each station must be carefully eliminated, and the data of numerous stations must be concentrated before anything like quantitative cosmical residuals can be obtained. When we consider that there have been numerous changes in the elevations of barometers, various methods of reducing the readings, and many groups of selected hours of observations entering into the series at the same station, how could it be expected that anything better than negative results in solar problems would be obtained? The skeptical attitude of conservative students, who declare that the many indecisive results already obtained mean that there is no true and causal solar-terrestrial synchronism, is, of course, quite fallacious until it has been demonstrated by the use of first-class homogeneous data that the suspected physical connection is imaginary. There is but little question that the existing uncertainty is in fact based upon the use of the very imperfect methods of observation and reduction which have prevailed in meteorological offices, rather than upon the unreality of the phenomena in nature."

The results of a comparison of Baltimore weather observations with the sunspot and solar prominence frequency curves have not differed from those arrived at in similar investigations elsewhere—they neither prove nor disprove an intimate relationship. As pointed out in preceding paragraphs there are synchronous changes here and there in the constantly fluctuating terrestrial conditions, but on the whole the evidence is negative. In view of the complicated character of the weather conditions, especially in our middle latitudes, a close agreement in phase of any periodic changes need scarcely be looked for, but the length of the period of the terrestrial and solar changes should harmonize.

In Fig. 84, the sunspot and solar prominence curves, constructed from Wolf's tables as printed in the Monthly Weather Review* are shown in connection with curves representing the *actual* annual changes at Baltimore in: (*a*) the mean pressure, (*b*) the mean temperature, (*c*)

*Monthly Weather Review of the U. S. Weather Bureau for April, 1902.

the total rainfall, (*d*) the frequency of thunderstorms, and (*e*) the frequency of storm winds (exceeding 25 miles per hour). In Plate XII, these facts have been presented again in a modified form, the annual values for the climatic conditions having been smoothed, eliminating some of the irregular fluctuations in order to show more clearly any periodic occurrences of longer period. The values employed in the construction of the curves of Plate XII were computed by means of the following formula, $\frac{a + 2b + c}{4}$ in which *a, b,* and *c* represent *actual* values for three successive years. In this manner a smoothed value was computed for each year of the entire series.

Plate XII contains in addition a record of all excessive rains at Baltimore from 1836 to 1904, an excessive rain being defined as a fall of 2.50 inches or more in 24 consecutive hours. These excessive rainfalls were taken from two distinct records; those occurring from 1871 to 1904 are a part of the official record of the U. S. Weather Bureau; those of the period from 1836 to 1870 are from the record of the Army Medical Department at Fort McHenry, with very few exceptions. The rainfalls of the earlier period are apparently too frequent, owing to the fact that there was more uncertainty in noting beginnings and endings of precipitation than in the later series. The earlier record doubtless contains excessive rains in which the time limit was extended to 30 or 36 hours. However, the grouping and relative frequency of these excessive falls are the features to which especial attention is called; the actual frequency is of less importance.

In a preceding paragraph reference was made to the fact that the periods of excessive frequency of heavy rains coincided very closely with the periods of minimum sunspot frequency from 1871 to 1904. The earlier observations were not then at hand. On extending the series of observations back to 1836, the same nice agreement does not hold good; there is a gradual change to a reversal in the phase of the sunspot period. However, the grouping is very striking, and the average length of the periods from maximum to maximum, or minimum to minimum, agrees very well with the average length of the sunspot and solar prominence periods.

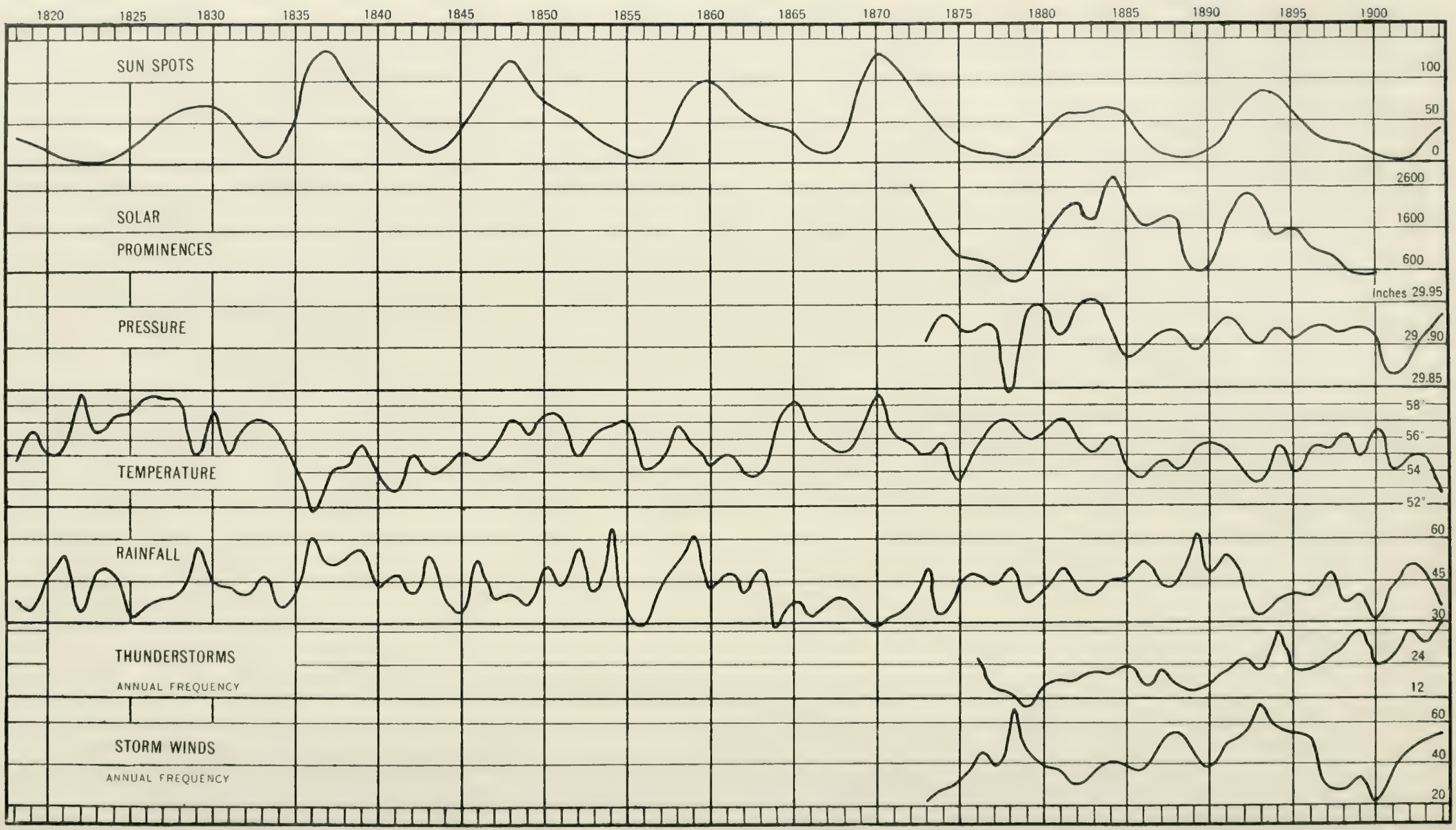
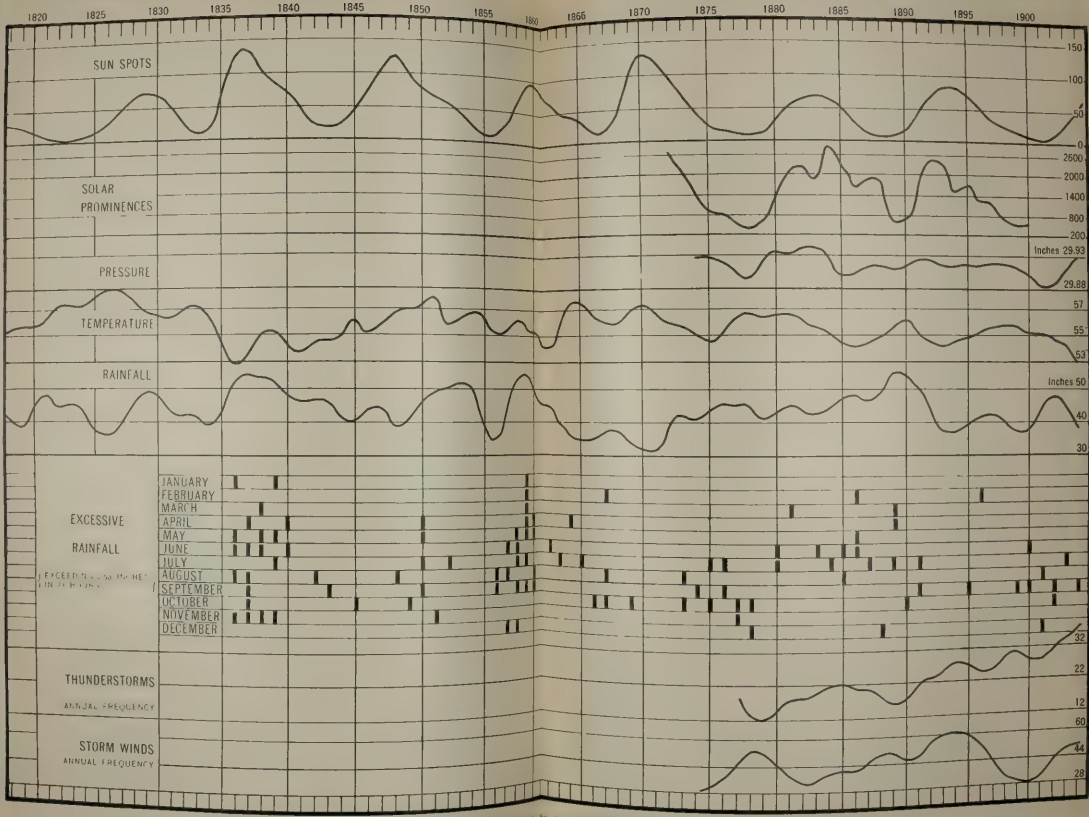


FIG. 84.—Sunspots, Solar Prominences and Weather Conditions. (Actual annual values employed in the construction of the curves.)



SUNSPOTS, SOLAR PROMINENCES AND WEATHER CONDITIONS.

(Smoothed annual values for weather conditions, excepting excessive rainfalls, which are observed values.)

These selected Baltimore observations are reproduced in Fig. 84 and Plate XII, not so much to call attention to any particular cycle of changes as to place them into convenient form for a critical study by some who may later find a more suitable clue to the solution of the difficult problem of the relationship between solar activity and terrestrial weather changes.

General Character of the Seasons.

The average values of climatic conditions and the departures from these values have been discussed in considerable detail in the text and tables of the preceding pages. To all but the expert in the study of statistical tables it is a difficult matter to derive, from a table of figures, no matter how perfect the arrangement, a satisfactory conception of the general character of a selected period, be it a day, a month, a season, or a year. The graphic method of presenting results appeals to a greater number because it enables the eye to take in at a glance relations between groups of values which would be more or less obscure to the casual reader when presented in tabular form. While recognizing the limitations of the graphic method for representing such a complex conception as the general character of the season, it has yet seemed profitable to resort to the use of a diagram for grouping such factors as are deemed most important in characterizing the weather conditions of a season.

The results are shown in Plates XIII to XVII, in which eight selected factors, expressed as departures from the normal climatic conditions at Baltimore, are presented for each season and year from 1871 to 1904. The choice of factors, as well as their arrangement, was a purely arbitrary matter, but they, as a matter of course, remain the same for each season and year. The method of charting may be briefly described here, although the legends on the plates will be found sufficiently clear for this purpose. The normal value of each of the climatic factors selected is represented by a point in the circumference of a circle, at the intersection of a radius representing one of the eight points of the compass. Taking for example the mean seasonal temperature: A departure above the normal would be represented by placing the point a given number of units beyond the circle along the extension of the radius representing

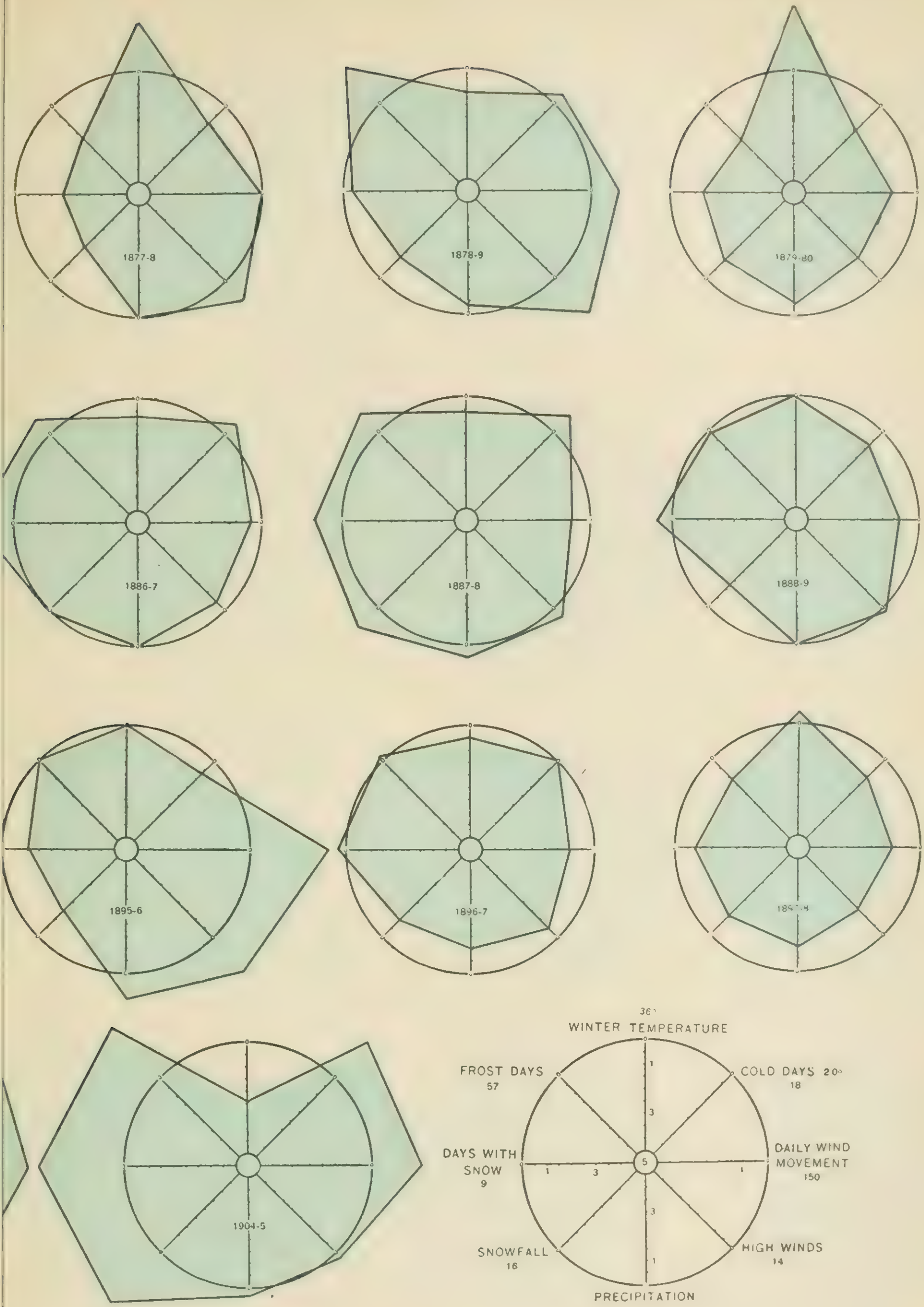
temperature; for a departure below the normal, the point would be placed within the circle along the same radius. By applying a similar method for each of the factors and joining the points thus located, we have a characteristic octagonal figure. A season having all its points located in the circumference of the circle would be represented by a regular octagon. The degree of departure from the regular octagon shows at a glance the amount and the character of the departure from normal climatic conditions of the season inspected. The unit adopted for measuring the amount of departure is the same in the discussion of all seasons and years, namely, the average variability of the factor. The average variability was obtained by adding up the individual departures for each season or year and dividing by the number of years employed.

The normal value for each factor is shown by the figures given below the designation of the factor in the key accompanying each set of diagrams. To bring the form representing the character of the season into further relief and separate it from the scale, the former is tinted. The comparison of the seasons at Baltimore from 1871 to 1904 will be found to be greatly facilitated by the use of these diagrams.

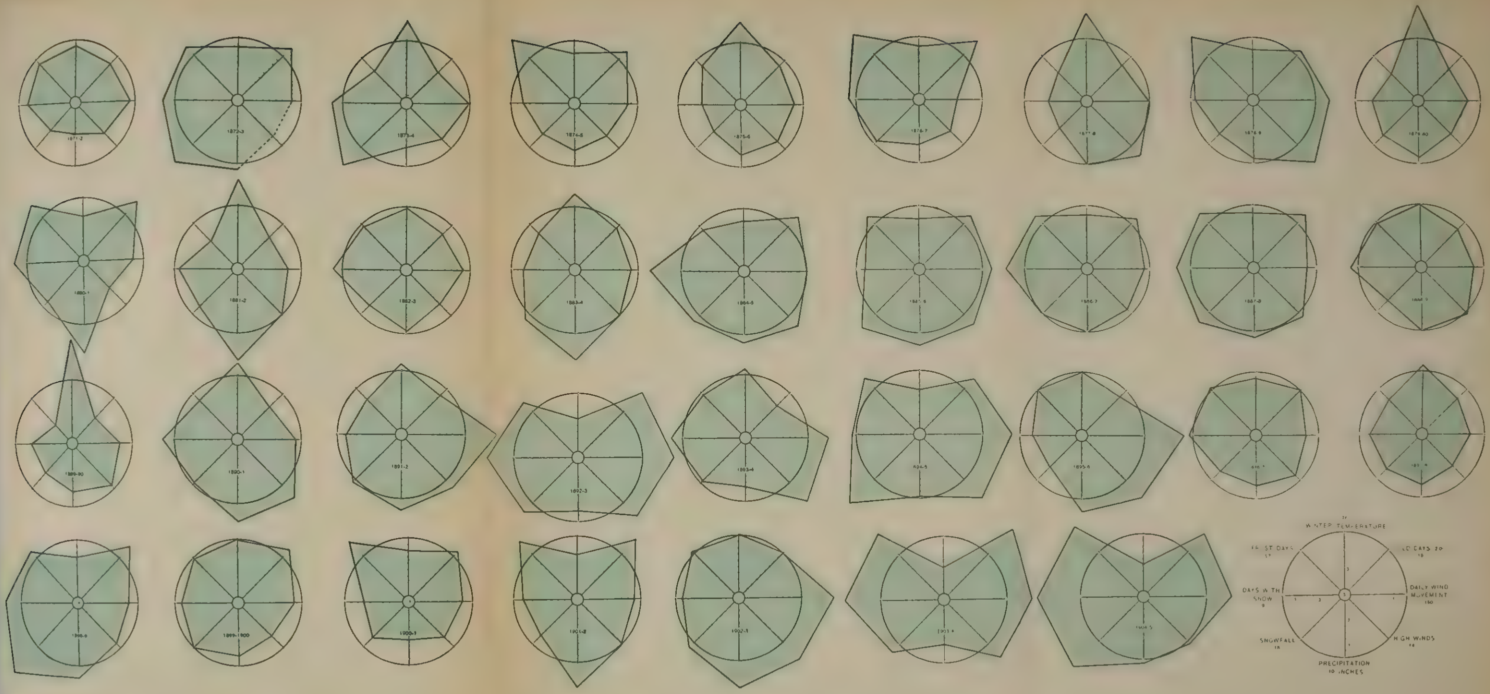
OBSERVATIONS AND INSTRUMENTAL EQUIPMENT.

Historical Notes.

Volume I of the Reports of the Maryland Weather Service (1899) contains a report upon the progress of meteorology in Maryland. References are there made to the early records of the weather which came to the notice of the writer, and to the development of systematic instrumental observations. While temperature records were regularly kept as early as 1753 in Prince George's County, we find no evidence of any instrumental observations within the limits of Baltimore City, or in the immediate vicinity, until the series made by Capt. Lewis Brantz, referred to in the preceding pages in connection with the discussion of temperature and rainfall. To the best of the writer's knowledge the very complete and accurate observations of Capt. Brantz were the earliest made within Baltimore City.

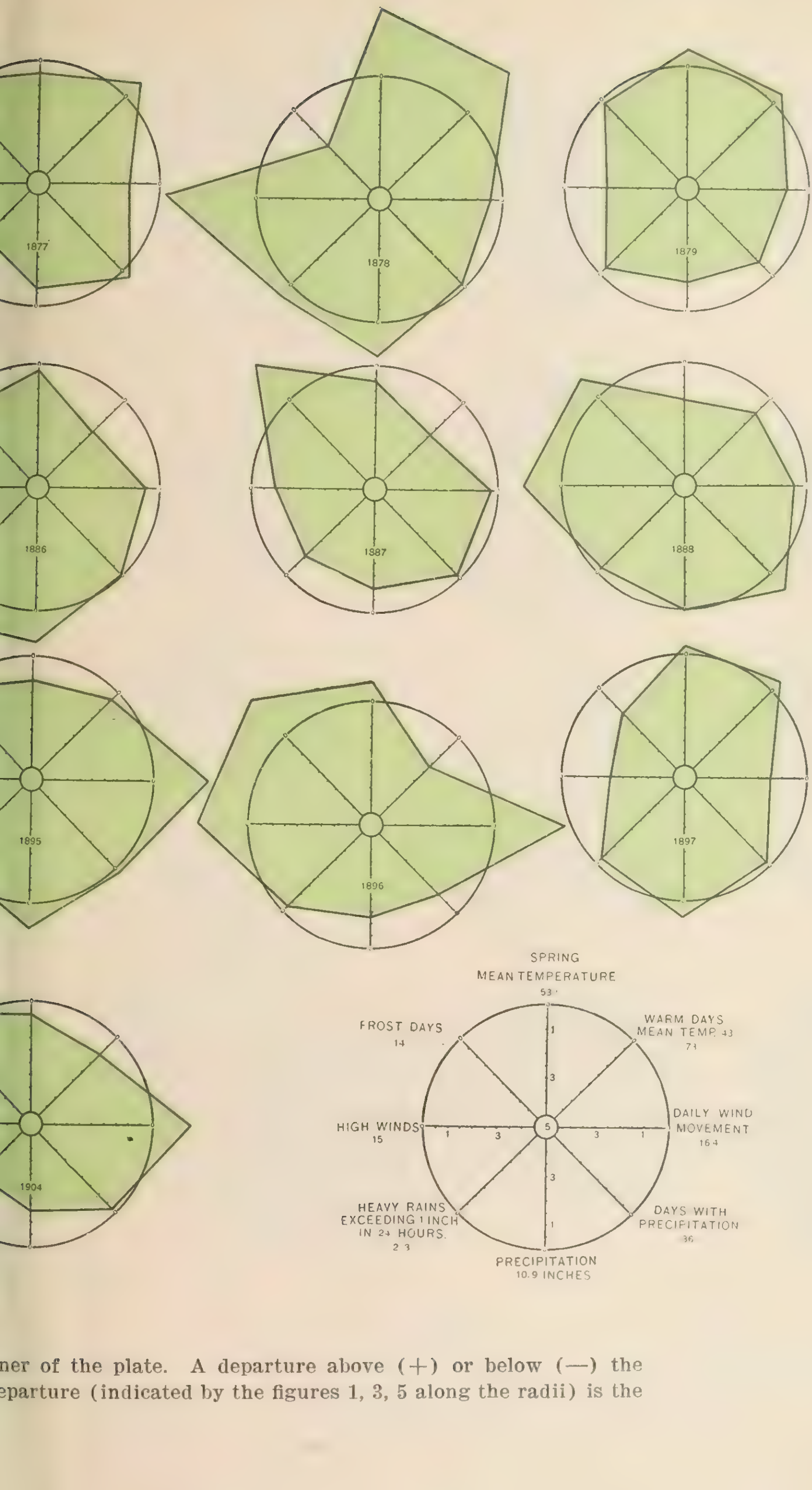


corner of the plate. A departure above (+) or below (—) the
departure (indicated by the figures 1, 3, 5 along the radii) is the



General Character of the Seasons.—Winter.

Points in the circumference of the circle, at the intersection of the radii (0), represent the average value of factors enumerated in the key in the lower right-hand corner of the plate. A departure above (+) or below (—) the average (or normal) value of the factor is shown by the position of points beyond or within the circle, respectively, and along a radius or its extension. The unit of departure (indicated by the figures 1, 3, 5 along the radii) is the average seasonal variability of the factor.



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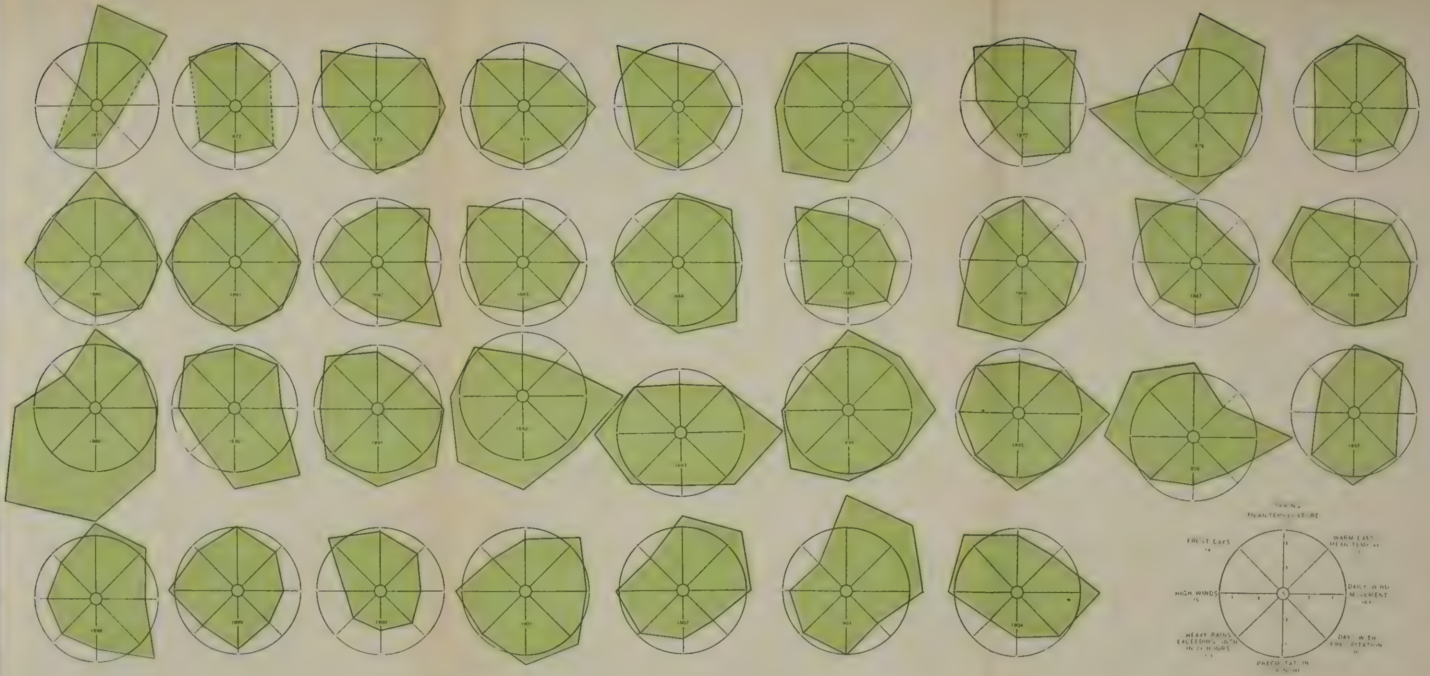
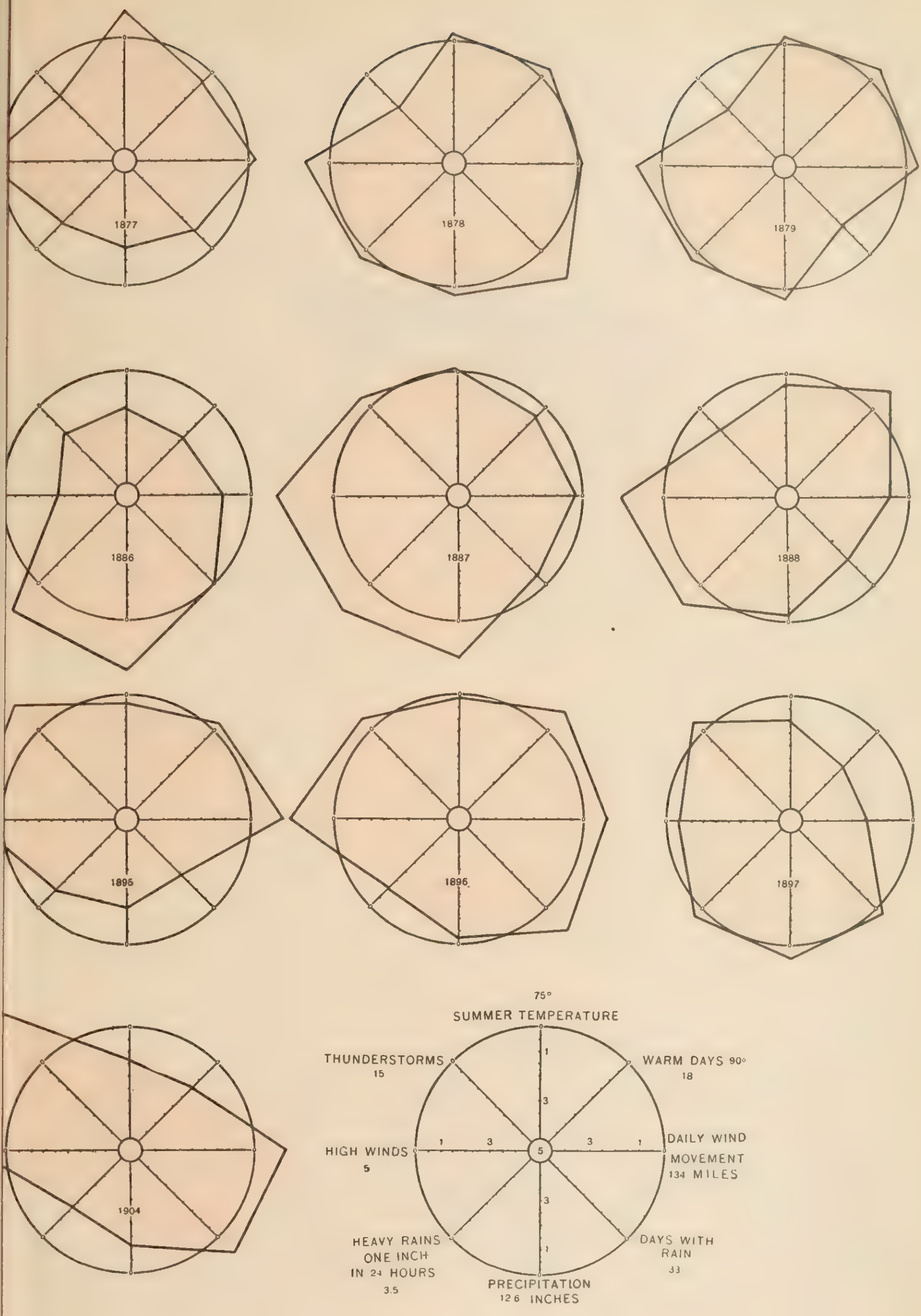
eparture (indicated by the figures 1, 3, 5 along the radii) is the

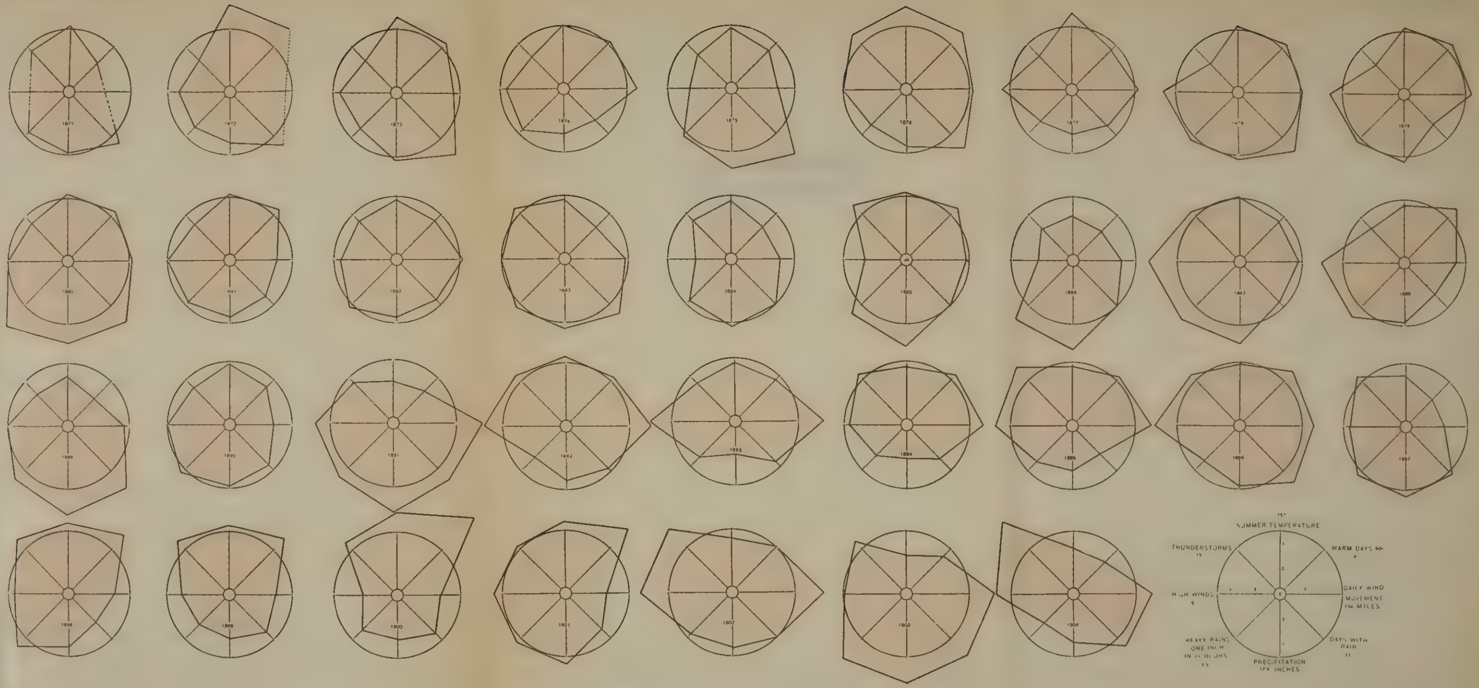


GENERAL CHARACTER OF THE SEASONS.—SPRING

Points in the circumference of the circle, at the intersection of the radii (0), represent the average value of factors enumerated in the key in the lower right-hand corner of the plate. A departure above (+) or below (—) the average (or normal) value of the factor is shown by the position of points beyond or within the circle, respectively, and along a radius or its extension. The unit of departure (indicated by the figures 1, 3, 5 along the radii) is the average seasonal variability of the factor.

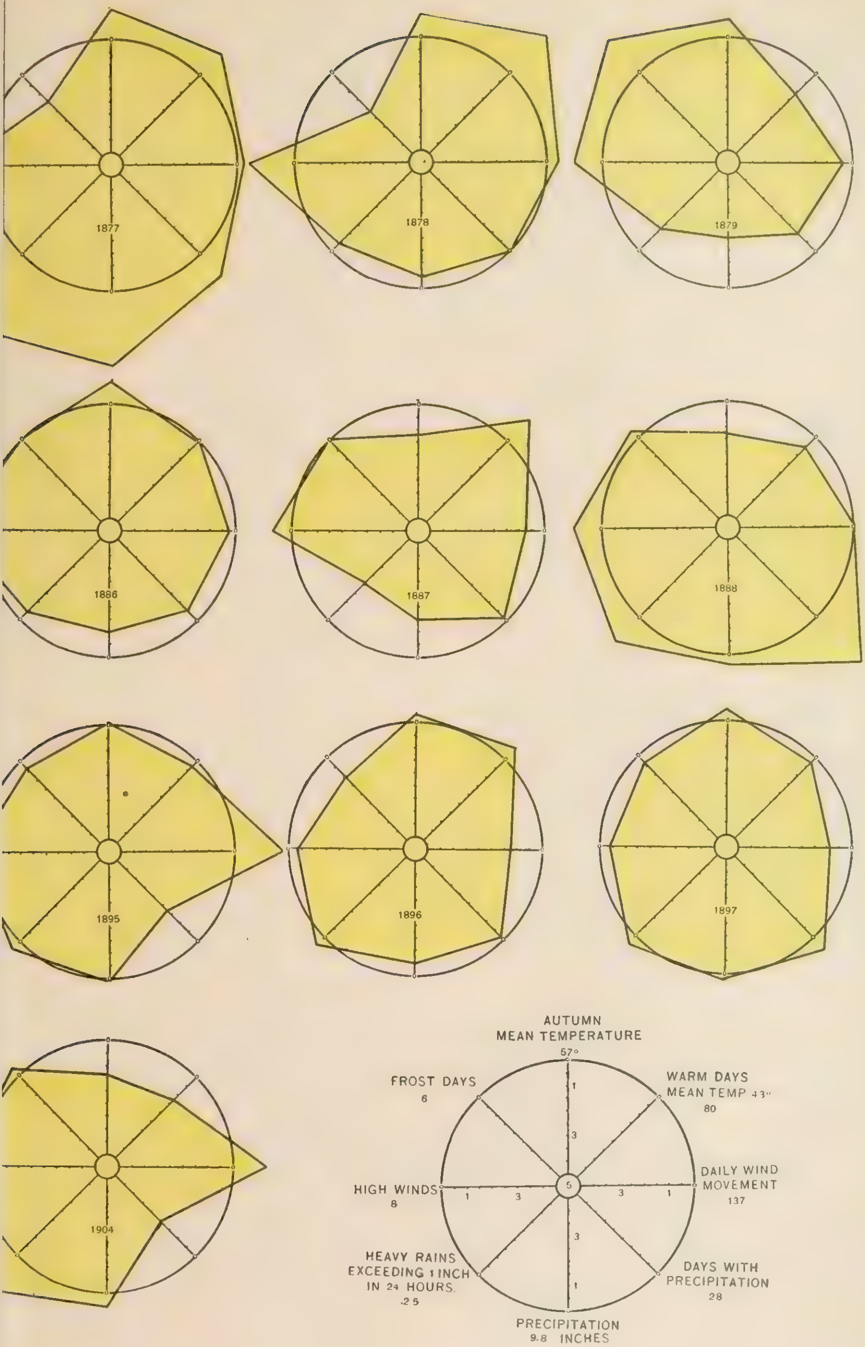


corner of the plate. A departure above (+) or below (—) the
of departure (indicated by the figures 1, 3, 5 along the radii) is the

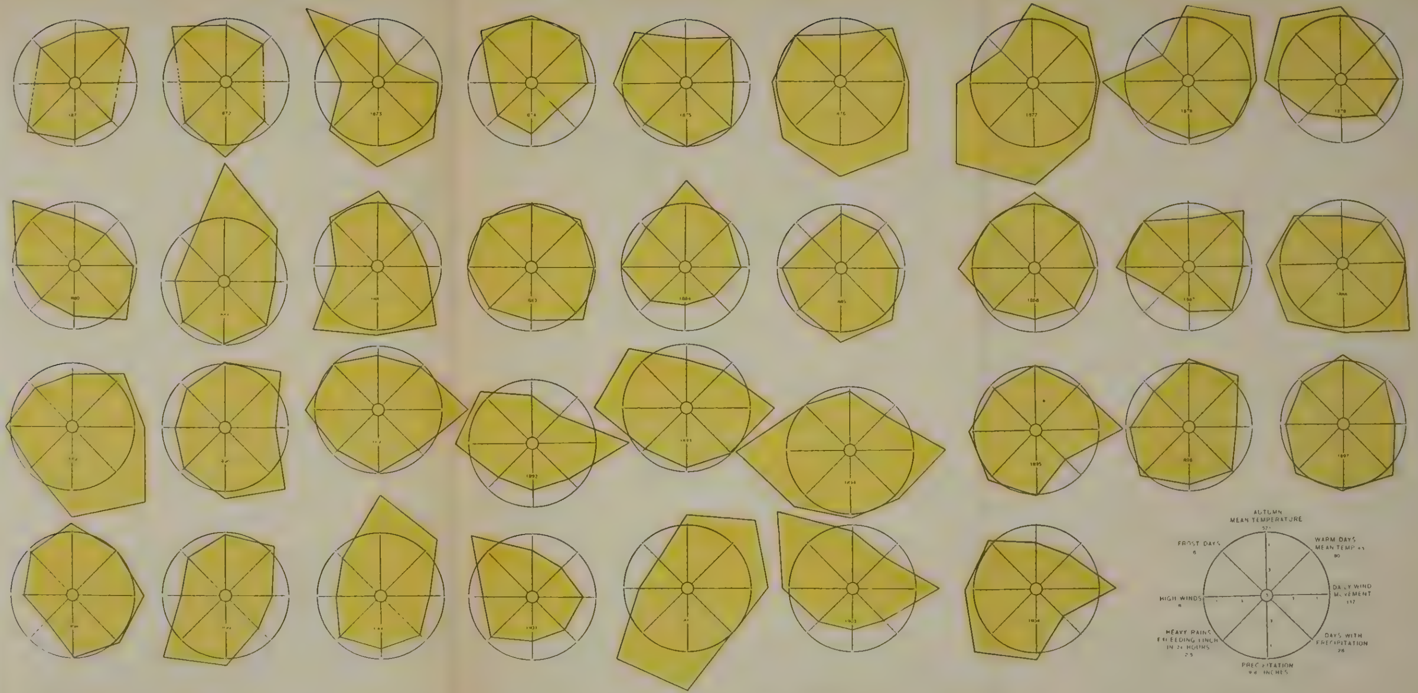


GENERAL CHARACTER OF THE SEASONS.—SUMMER.

Points in the circumference of the circle, at the intersection of the radii (0), represent the average value of factors enumerated in the key in the lower right-hand corner of the plate. A departure above (+) or below (—) the average (or normal) value of the factor is shown by the position of points beyond or within the circle, respectively, and along a radius or its extension. The unit of departure (indicated by the figures 1, 3, 5 along the radii) is the average seasonal variability of the factor.

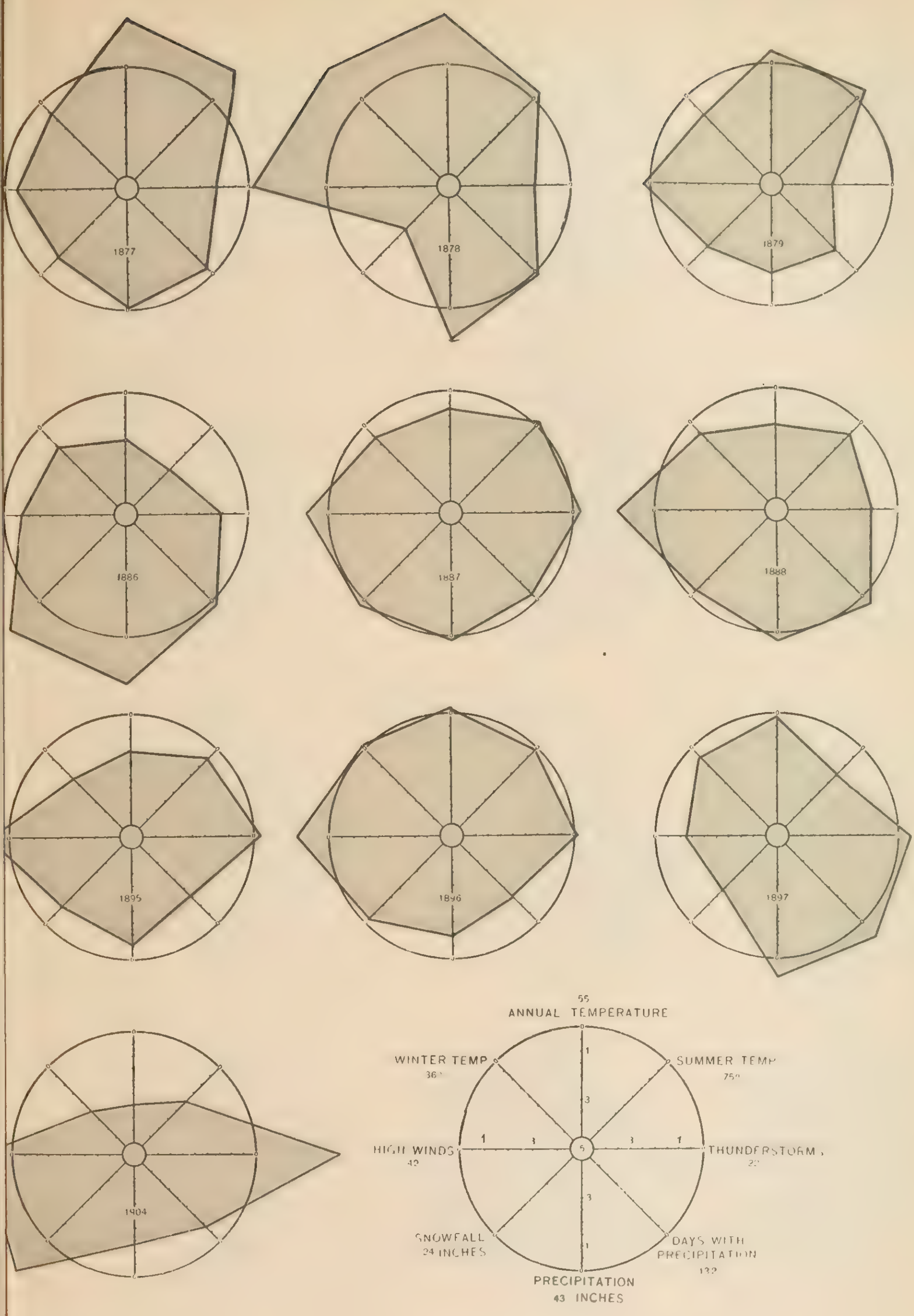


corner of the plate. A departure above (+) or below (—) the
of departure (indicated by the figures 1, 3, 5 along the radii) is the

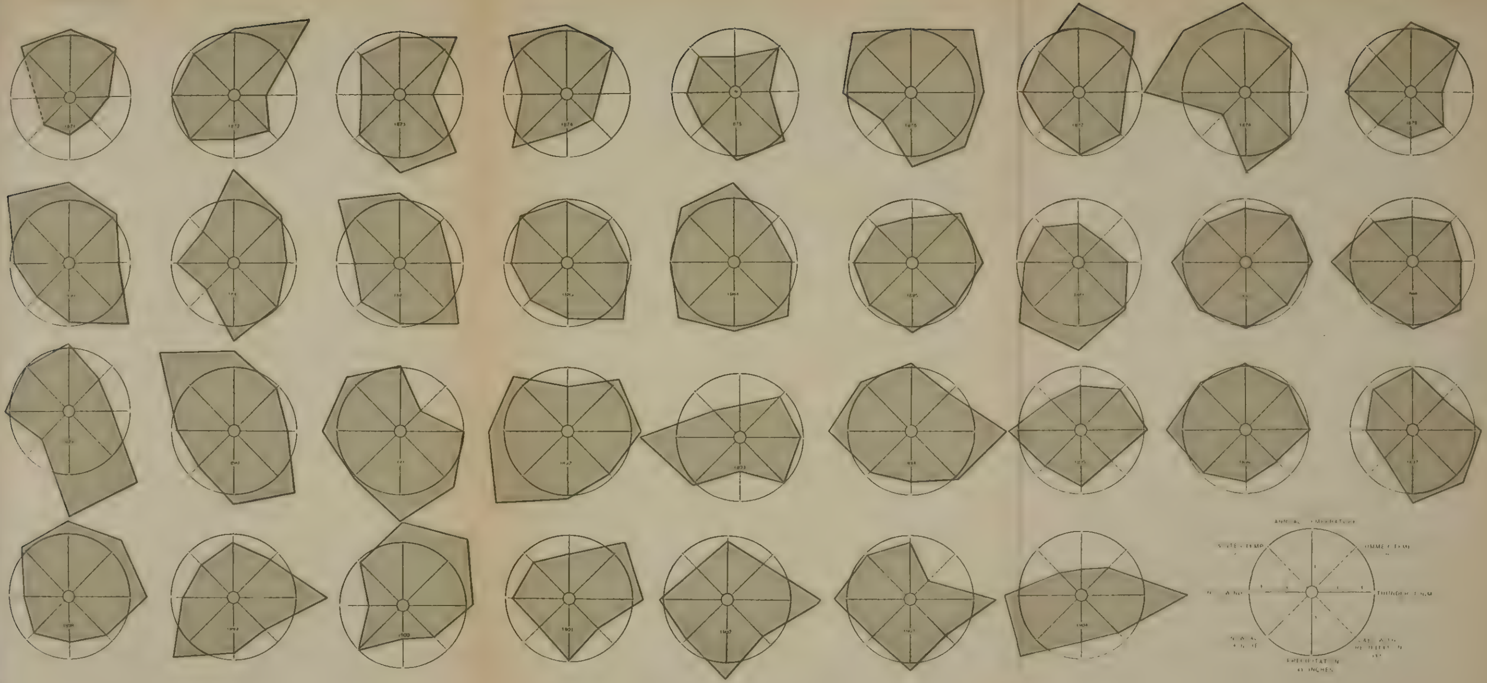


GENERAL CHARACTER OF THE SEASONS.—AUTUMN.

Points in the circumference of the circle, at the intersection of the radii (0), represent the average value of factors enumerated in the key in the lower right-hand corner of the plate. A departure above (+) or below (−) the average (or normal) value of the factor is shown by the position of points beyond or within the circle, respectively, and along a radius or its extension. The unit of departure (indicated by the figures 1, 3, 5 along the radii) is the average seasonal variability of the factor.



corner of the plate. A departure above (+) or below (—) the
of departure (indicated by the figures 1, 3, 5 along the radii) is the



GENERAL CHARACTER OF THE YEAR

Points in the circumference of the circle, at the intersection of the radii (0), represent the average value of factors enumerated in the key in the lower right hand corner of the plate. A departure above (+) or below (—) the average (or normal) value of the factor is shown by the position of points beyond or within the circle, respectively, and along a radius or its extension. The unit of departure (indicated by the figures 1, 3, 5 along the radii) is the average seasonal or annual variability of the factor.

Some years later, in 1831, a station of the U. S. Army Medical Department was established at Fort McHenry, where observations were maintained with but little interruption until 1892. Between 1830 and 1840, two or three individual Baltimore observers sent occasional reports to the Maryland Academy of Sciences, or to the Franklin Institute in Philadelphia.

The Smithsonian Institution was established in 1847, and very soon after numerous voluntary observers reported weather conditions regularly from different parts of the State. The Baltimoreans who cooperated with the institution between 1850 and 1860 were Dr. A. Zumbrock (1850-52), Dr. Lewis H. Steiner (1853), and Prof. Alfred W. Mayer (1857-59).

In the year 1870, the U. S. Weather Bureau (then known as the U. S. Signal Service) was established by act of Congress. The Baltimore station was among the first to be opened, and observations were maintained without the interruption of a single day until the present time. The instrumental equipment was always of the first order and was steadily increased with the growth of the Bureau. During the past ten years, continuous records of air pressure, temperature, wind velocity and direction, sunshine, and rainfall, by means of self-recording instruments, have been maintained. In 1902, a Richard hygrograph was added, the property of the Maryland State Weather Service. Details concerning the history and equipment of the U. S. Weather Bureau station are given in the following pages in tabular and statistical form for ready reference, including changes in the location of the observing station, in the elevation of instruments and in the personnel of the station.

In 1891, the Maryland State Weather Service was organized; the purpose and method of organization are fully described by the director in Volume I, of the Reports of the Maryland Weather Service, issued in 1899. From the beginning there has always been an intimate and harmonious cooperation between the National Service, the State Service, and the Johns Hopkins University. The offices of the U. S. Weather Bureau and of the Maryland Weather Service have been in the buildings of the University since the establishment of the State Service. The Board of Control of the Maryland Service comprises a representative of

METEOROLOGICAL OBSERVERS AND OBSERVATIONS IN BALTIMORE, MD.

Observer	Location	Auspices.	North Latitude	Longitude West of Greenwich	Elevation in feet	Period	Hours of Observation	Items Observed	Remarks
			° ′	° ′					
Capt. Lewis Brantz	West part of city	Private	39 17	76 37	80	1817-1824; Jan. to Aug., 1829; Nov. 1836 to June, 1837	8 a. m., 2 p. m. and 10 p. m.	Temperature, rainfall, winds, clouds; Barometer and hygrometer added in 1836.	Published in pamphlet form from 1818 to 1825; reprinted in the American Almanac, 1834, and in other publications.
Post Surgeons, U. S. A.	Fort McHenry	U. S. Army	39 16	76 35	36	1831 to June, 1859; Apr., 1861 to Jan., 1862; 1864 to Feb., 1892	7 a. m., 2 p. m. and 9 p. m.	Temperature, humidity, wind direction and weather; rainfall added in May, 1836.	
Dr. G. S. Sproston, U. S. N.		Private	39 17	76 37	50	1835 to 1836	7 a. m., 2 p. m. and 9 p. m.	Temperature, wind direction and rainfall	Occasional reports to Franklin Institute of Philadelphia
Md. Academy of Science and Literature		Md. Acad. Sci. and Lit.	39 17	76 36	53	1836, 21 and 22, June, Sept. and Dec.	Hourly	Pressure, temperature, wind direction and velocity, hygrometer, cloud movement and state of weather.	Published in Trans. Md. Acad. Sci., Vol. I, 1837.
Dr. T. Edmondson, Jr.	West part of city	Private	39 18	76 38	193	1835 to 1837; 1846 to Oct. 1853	Sunrise, 10 a. m., 3 p. m. and 7 p. m.	Pressure, temperature, wind direction and force, dewpoint, rainfall and weather	Printed copies of reports for Jan., Mar., July and Aug. presented to Maryland Academy of Science
Dr. A. Zumbrock		Smithsonian Institution	39 17	76 37	50	Apr., 1850 to July, 1852	7 a. m., 2 p. m. and 9 p. m.	Temperature, wind direction and rainfall	
Dr. Lewis H. Steiner	Baltimore Medical Institute	Smithsonian Institution	39 17	76 37	258	Jan. to Oct., 1853	7 a. m., 2 p. m. and 9 p. m.	Pressure, temperature, winds, clouds, rainfall, relative humidity	
Prof. Alfred M. Mayer		Smithsonian Institution	39 18	76 37	50	Nov., 1857 to Aug., 1859	7 a. m., 2 p. m. and 9 p. m.	Temperature, wind direction and rainfall	
Wm. Luther Woods	Johns Hopkins Hospital	Maryland S. W. S. and U. S. W. Bureau	39 18	76 36	112	Nov. 1894 to date	Self registering maximum and minimum thermometer	Temperature, wind direction, weather and rainfall	
*U. S. Weather Bureau (U. S. Signal Service until July 1, 1891	Johns Hopkins University	United States Government	39 18	76 37	†123	Jan., 1871 to date	See page 302 for hours of observation	Daily observations at stated hours, since Jan. 1, 1871 of pressure, temperature, wind direction and velocity, humidity, clouds and rainfall, temperature of water in harbor Sept. 1881 to March, 1887; atmospheric electricity, 1882 to 1887. Continuous automatic record of wind velocity since Jan., 1871, wind direction since 1874, rainfall since Nov., 1892; pressure and temperature since Jan., 1893; sunshine since July, 1893; humidity since Feb., 1902.	

* For earlier locations and elevations see page 304.

† Barometer elevation above sea level

each of the three institutions. Since 1896, the system of voluntary observing stations established in 1891, and later, by the State Service, and the publication of weekly and monthly reports, have been under the control of the National Service. The special appropriation by the State has since been devoted to the investigation of special climatic problems and the publication of the results.

The local office of the U. S. Weather Bureau is intimately associated with the commercial organizations of the city. The results of observations and specially prepared reports are quickly put into the possession of those most benefited thereby through the instrumentality of the public press, by special bulletins, by telephone, or otherwise. Special efforts have always been made to place the daily telegraphic reports of weather conditions from all parts of the country before the commercial interests at the earliest possible hour each day. These reports, as soon as received, are placed upon a large glass map upon the floor of the Chamber of Commerce, by means of symbols and lines; the Baltimore station was among the earliest to adopt this method of publishing the daily weather conditions.

One of the most important duties of the local office of the Weather Bureau is the prompt distribution of the daily forecasts to the public, and of special warnings of the approach of storms, or cold waves, or the occurrence of frost. This is accomplished by a liberal use of the telegraph and the telephone, and by the hearty cooperation of the public press and the U. S. Postal authorities, especially through the instrumentality of the recently established system of rural free delivery, by means of which the daily weather forecasts are being placed regularly each day in possession of all who dwell along the established routes, even those in remote farming communities.

The shipping interests are informed directly by telephone of the approach of a severe storm; the owners of the smaller craft in the neighboring waters depend mostly for their information upon the display of storm warnings at a conspicuous point along the harbor by means of special storm flags by day and lights by night. For many years, these special warnings were displayed from the flag staff on Federal Hill; they

OFFICE OF THE U. S. WEATHER BUREAU,
JOHNS HOPKINS UNIVERSITY, No. 532 NORTH HOWARD STREET.

MARYLAND STATE WEATHER SERVICE.

are now displayed from the top of a steel tower, 50 feet in height, erected upon the roof of the seamen's home, known as "The Anchorage," at the intersection of South Broadway and Thames Streets in East Baltimore.

Reports on the weather and crop conditions throughout the States of Maryland and Delaware have been printed and widely distributed from the local office each week during the season of crop growth from 1891 to the present time. Monthly and annual reports have also been issued during the same period, showing the daily weather conditions and the monthly and annual average values, together with the progress of crop growth and farm operations from month to month. A printed daily weather map (single sheets 11 in. by 16 in. in size) was issued from the local office from October, 1896, to November, 1898. These received a free and wide distribution in the business portions of Baltimore and among educational institutions. The maps showed the weather conditions over the entire country, based on over a hundred telegraphic reports of observations made each morning at 8 a. m., 75th meridian time. They reached the public about 1 p. m. each day. In November of 1898, the printing office connected with the Baltimore station was closed and the daily weather map was replaced by the larger and more complete lithographic map issued from the Central Office at Washington, D. C.

Observers and Observations.

The table on pages 298 and 299 contains a list of the individuals and institutions responsible for systematic instrumental observations of the weather within the city limits of Baltimore. The geographical location of the station, the period, and the character of the observations are also stated as far as known. There were doubtless other observers but their contributions to the observational literature of meteorology in Baltimore have not come under the notice of the writer.

Instrumental Equipment.

The instruments in use at the local station of the U. S. Weather Bureau since the organization of the Service in 1871 are enumerated in the following list; the dates of installation and discontinuance of the instruments are also given:

Instruments	In Use Since	Use Discontinued
Anemometer, Robinson	Jan. 1, 1871	
Anemoscope	Jan. 1, 1871	
Barograph, Richard	Dec. 30, 1892	
Barometer (Mercurial)	Jan. 1, 1871	
*Hygrograph, Richard	Feb., 1902	
Hygrometer, stationary	Jan. 1, 1871	July 11, 1886
Psychrometer (whirling)	July 11, 1886	
Rain Gage (ordinary)	Jan. 1, 1871	
Rain Gage (self-registering, float)	May 30, 1891	June 20, 1897
Rain Gage (self-registering, tipping bucket)	June 13, 1897	
*Rain recorder, continuous	Jan., 1903	
Register, single (wind velocity)	Jan. 1, 1871	Feb. 10, 1874
Register, double (wind velocity and direction)	Feb. 10, 1874	Nov. 10, 1892
Register, triple (wind velocity, direction and rain)	Nov. 10, 1892	
Snow Gage	Jan. 1, 1871	
Sunshine Recorder (added to triple register)	June 30, 1893	
Shelter, standard window	Jan. 1, 1871	Sept. 30, 1885
Shelter, standard roof	Oct. 1, 1885	
Thermograph, Richard	Dec. 30, 1892	
Thermometer, dry bulb	Jan. 1, 1871	
Thermometer, maximum	July 22, 1872	
Thermometer, minimum	July 22, 1872	
Thermometer, water	Sept. 1, 1881	Mar. 31, 1887

* Property of the Maryland State Weather Service.

Hours of Observation.

The prescribed hours of observation, as well as the kind of time employed in the National Service, have been changed from time to time since the organization of the Bureau in 1870. Local time was in use at all stations from January 1, 1871, to July 31, 1881; on August 1, 1881, Washington time was adopted, making a difference of two minutes between the local times of observation in Washington and Baltimore. Since January 1, 1885, observations have been made on 75th meridian time. The difference between Baltimore local time and 75th meridian time is six minutes, the former being slower than the latter by this amount.

The combination of selected hours for observation has varied considerably in the thirty-four years since 1871. From 1871 to June 30, 1888, at least three direct observations were made daily, one at an early morning hour, from 7 a. m. to 7 :30 a. m., another in the middle of the afternoon, at 2 p. m., 3 p. m., or 4 :30 p. m., a third at night between 9

p. m. and 11:30 p. m. Five observations were made daily for some years. Since July, 1888, there have been but two observations, one at 8 a. m., another at 8 p. m. The exact hours of observation and the duration of their employment are indicated in the following tabular statement:

HOURS OF OBSERVATION.

(U. S. Weather Bureau, 1871-1904.)

Time of Observation.		Began.	Ended.
7:37 a. m. (l. t.)	Telegraphic	Jan. 1, 1871	Oct. 31, 1879
4:37 p. m. (l. t.)	Telegraphic	Jan. 1, 1871	Oct. 31, 1879
11:37 p. m. (l. t.)	Telegraphic	Jan. 1, 1871	Aug. 24, 1872
11:02 p. m. (l. t.)	Telegraphic	Aug. 25, 1872	Dec. 31, 1884
7:00 a. m. (l. t.)		Jan. 1, 1871	June 30, 1881
2:00 p. m. (l. t.)		Jan. 1, 1871	June 30, 1881
9:00 p. m. (l. t.)		Jan. 1, 1871	June 30, 1881
12:02 p. m. (l. t.) (special)		Oct. 22, 1871	Feb., 1872
12:02 p. m. (l. t.) (daily)		Feb. 23, 1873	Dec. 31, 1879
11:02 a. m. (l. t.)		Jan. 1, 1880	Dec. 31, 1884
7:02 p. m. (l. t.)		July 1, 1881	Dec. 31, 1884
7:02 a. m. (l. t.)	Telegraphic	Nov. 1, 1879	July 31, 1881
7:00 a. m. (w. t.)	Telegraphic	Aug. 1, 1881	Dec. 31, 1884
3:02 p. m. (l. t.)	Telegraphic	Nov. 1, 1879	July 31, 1881
3:00 p. m. (w. t.)	Telegraphic	Aug. 1, 1881	Dec. 31, 1884
11:02 p. m. (l. t.)	Telegraphic	Aug. 25, 1872	July 31, 1884
11:00 p. m. (w. t.)	Telegraphic	Aug. 1, 1884	Dec. 31, 1884
2:00 p. m. (w. t.)	Water temperatures	Sept. 1, 1881	Dec. 31, 1884
2:00 p. m. (75th m. t.)	Water temperatures	Sept. 1, 1881	Mar. 31, 1887
7:00 a. m. (75th m. t.)	Telegraphic	Jan. 1, 1885	June 30, 1888
3:00 p. m. (75th m. t.)	Telegraphic	Jan. 1, 1885	June 30, 1888
11:00 p. m. (75th m. t.)	Telegraphic	Jan. 1, 1885	Dec. 31, 1886
10:00 p. m. (75th m. t.)	Telegraphic	Jan. 1, 1887	June 30, 1888
11:00 a. m. (75th m. t.)		Jan. 1, 1885	Aug. 3, 1886
7:00 p. m. (75th m. t.)		Jan. 1, 1885	Aug. 3, 1886
8:00 a. m. (75th m. t.)	Telegraphic	July 1, 1888	Current
8:00 p. m. (75th m. t.)	Telegraphic	July 1, 1888	Current
Local time (l. t.) 6 min. slower than 75th m.		Jan. 1, 1871	July 31, 1881
Washington (w. t.) 8 min. slower than 75th m.		Aug. 1, 1881	Dec. 31, 1884
75th meridian time		Jan. 1, 1885	Current

Changes in the Location of the Station.

Changes in the location of the observing station of the U. S. Weather Bureau have necessitated changes in the elevation of instruments. During a period of 34 years, five different stations have been occupied. The office has always been in the thickly settled portion of the city; from 1871 to 1889 in the heart of the business section, later in the buildings of the Johns Hopkins University, No. 532 North Howard Street. The details of the changes experienced in station and instruments are indicated in the tabular statement below. With unimportant exceptions, the instruments have always had a fairly free exposure, as good, perhaps, as can be had in the midst of a large city.

LOCATION OF U. S. WEATHER BUREAU STATIONS AND ELEVATION OF INSTRUMENTS.

Location.	Floor.	Observations begun.	North latitude.	Longitude in feet.	Above sea level: Barometer (Feet).	Above Ground (Feet). Barometer.	Thermometers.*	Rain Gage.	Anemometer.	Wind Vane.
Fireman's Insurance Building, S. W. Cor. South & Water Sts......	3d	Jan. 1, 1871 Oct. 12, 1878 Oct. 1, 1885	39° 18′	76° 37′	45	32	33 76	69	75 86	85 95
Neal Office Building, S. W. Cor. Holliday & Baltimore Sts...........	4th	Jan. 1, 1889	39° 18′	76° 37′	76	56	86	78	100	110
Johns Hopkins University, Physical Laboratory, N. W. Cor. Linden Ave. & Monument St....	Upper floor of tower	June 1, 1891 1892	39° 18′	76° 37′	179	71	87	78 80	100	110
Equitable Building, S. W. Cor. Calvert & Fayette Sts...............	9th	Sept. 7, 1895	39° 18′	76° 37′	142	105	120	116	136	146
Johns Hopkins University, Treasurer's Building, No. 532 N. Howard St........................	2d	Aug. 1, 1896 Apr. 30, 1902 Oct. 1, 1902	39° 18′	76° 37′	123	20	68 69	73	82 117	94 115

*Thermometers in louvered window shelter on north side of building from Jan., 1871 to Sept. 30, 1885; later in standard shelter on the roof of the station building. On Oct. 1, 1902, the standard shelter was mounted within the 50 ft. steel tower supporting the wind vane and the anemometer, the base of the shelter being nine feet above the roof.

STORM WARNING DISPLAY STATION,
THE "ANCHORAGE," FOOT OF BROADWAY, BALTIMORE MD.

VARIATIONS IN THE ELEVATION OF THE BAROMETER AND CORRECTIONS TO THE EPOCH, JANUARY 1, 1900.*

Barometer above reference plane.. 25.3 feet.
Reference plane, top of iron pipe underneath sidewalk on west side of Howard street opposite Center street, transverse station No. 482 of the City of Baltimore Topographical Survey, above mean sea level.................................. 98.0 "

Station elevation of barometer, Jan. 1, 1900..123.3 "

Date of change.	Buildings Occupied.	Elevation (Feet.)	Change in the actual elevation. (Feet.)	Difference between actual and station elevations. (Feet.)	Correction for difference in elevation.	Correction for gravity.	Total correction.
1870, Dec. 23	Southwest corner of South & Water streets	45.2	..	+78.1	−.088	−.015	−.103
1889, Jan. 1	Southwest corner of Baltimore and Holliday streets	75.9	+30.7	+47.4	−.054	−.015	−.069
1891, June 1	Johns Hopkins University (Physical Laboratory)	178.8	+102.9	−55.5	+.063	−.015	+.048
1895, Sept. 7	Southwest corner of Calvert and Fayette streets	141.5	−37.3	−18.2	+.020	−.015	+.005
1896, Aug. 1	Johns Hopkins University (No. 532 North Howard street)	123.3	−18.2	..	..	−.015	.015
1899, Jan. 1		..	..	..	..	..	.000

* For further information regarding the reduction of barometric observations see: Bigelow, F. H. The Reduction of Barometric Pressure Observations at Station of the United States Weather Bureau. Vol. II of the Report of the Chief of the U. S. Weather Bureau for 1900.

OFFICIALS IN CHARGE, U. S. WEATHER BUREAU OFFICE, BALTIMORE. (1871-1904)

Name.	Official title.	Date of assignment.	Date of relief.
Cowan, J. E.	Sergeant	Jan. 1, 1871	Mar. 27, 1871
Penrod, H. J.	Sergeant	May 12, 1871*	Sept. 23, 1874
Boyd, W. T.	Sergeant	Sept. 24, 1874	April 24, 1875
Kabernagle, J.	Sergeant	April 25, 1875	Dec. 20, 1875
Bell, R. J.	Sergeant	Dec. 21, 1875	May 21, 1877
McGann, E. W.	Sergeant	May 30, 1877*	June 6, 1879
Black, W.	Sergeant	June 16, 1879*	Aug. 29, 1879
Seyboth, Robt.	Sergeant	Oct. 24, 1879*	Sept. 6, 1882
Felger, G. W.	Sergeant	Sept. 7, 1882	Oct. 26, 1888
Cronk, C. P.	Sergeant	Oct. 27, 1888	July 6, 1895
Marbury, J. B.	Local Forecast Official	July 7, 1895	July 1, 1896
Hunt, G. E.	Local Forecast Official	July 2, 1896	May 22, 1897
Walz, F. J.	Local Forecast Official	May 23, 1897	May 29, 1900
Fassig, O. L.	Section Director	July 2, 1900*	In charge

* During intervening intervals the station was in charge of the first assistant.

SUMMARY OF AVERAGE AND EXTREME VALUES (1871-1904).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
I. PRESSURE (inches and thousandths).													
Mean Monthly Pressure	29.995	29.968	29.899	29.877	29.852	29.851	29.850	29.869	29.946	29.942	29.976	29.988	29.917
Highest Monthly Mean	30.083	30.155	30.073	29.983	29.994	29.935	29.924	29.936	30.024	30.053	30.117	30.077	29.955
Lowest Monthly Mean	29.847	29.762	29.642	29.689	29.726	29.773	29.744	29.761	29.850	29.771	29.830	29.911	29.845
Greatest Range	0.236	0.393	0.431	0.294	0.268	0.162	0.180	0.175	0.174	0.282	0.287	0.166	0.110
Mean Monthly Variability	0.059	0.055	0.058	0.054	0.045	0.029	0.030	0.033	0.032	0.055	0.059	0.046	0.015
Mean Monthly Maximum	30.572	30.557	30.443	30.353	30.245	30.191	30.151	30.159	30.293	30.381	30.498	30.540	30.694
Mean Monthly Minimum	29.307	29.298	29.291	29.363	29.502	29.542	29.594	29.608	29.581	29.435	29 420	29.352	29.120
Mean Monthly Range	1.265	1.259	1.152	0.990	0.743	0.649	0.557	0.551	0.712	0.946	1.078	1.188	1.574
Absolute Maximum	30.843	30.849	30.650	30.550	30.424	30.414	30.359	30.342	30.440	30.752	30.740	30.830	30.849
Absolute Minimum	28.908	28.809	28.992	28.969	29.257	29.345	29.457	29.350	29.181	28.739	28.902	28.648	28.648
Absolute Range	1.935	2.040	1.658	1.581	1.167	1.069	0.902	0.992	1.259	2.013	1.838	2.182	2.201
II. TEMPERATURE (degrees Fahr.).													
Mean Monthly Temperature	34.0	35.5	42.1	53.3	64.3	73.1	77.6	75.6	68.4	57.5	46.0	37.1	55.3
Highest Mean Monthly Temperature	43.7	43.0	49.7	58.9	70.8	75.9	81.7	80.3	77.2	63.5	51.7	45.1	57.2
Lowest Mean Monthly Temperature	24.3	26.2	35.4	47.0	59.6	67.5	71.6	72.7	63.7	52.9	41.5	29.0	53.4
Mean Monthly Departures from the Normal	3.4	3.9	3.1	2.5	2.1	1.8	1.6	1.6	2.0	2.4	2.5	2.9	1.1
Mean Daily Maximum	40.6	42.4	49.6	61.6	72.9	81.8	85.8	83.3	76.5	65.6	53.1	43.8	63.1
Mean Daily Minimum	27.4	28.5	24.4	44.8	55.6	64.5	69.4	67.3	60.4	49.2	38.7	30.3	47.5
Mean Daily Range	13.2	13.9	15.2	16.8	17.3	17.3	16.4	16.0	16.1	16.4	14.4	13.5	15.6
Extreme Daily Range	42	47	36	38	39	31	32	30	38	35	31	42	47
Mean Daily Change	1.0	1.0	1.2	0.8	1.0	0.6	0.6	0.4	0.9	0.7	1.0	0.8	0.8
Mean Daily Departure from the Normal	7.1	..	..	5.1	..	..	3.7	..	..	6.4	..	..	5.6
Absolute Monthly Maximum	73	78	82	94	96	99	10.4	100	101	90	79	73	104
Absolute Monthly Minimum	–6	–7	5	24	34	47	55	51	39	30	15	–3	–7
Absolute Monthly Range	79	85	77	70	62	52	49	49	62	60	64	76	111
Average Number of Frost Days (Minimum of 32° or less)	21.6	18.8	12.3	1.9	..	..	..	..	..	0.2	6.1	17.5	78.4
Greatest Number of Frost Days	29	28	21	6	0	0	0	0	0	2	16	30	114
Least Number of Frost Days	9	10	2	0	0	0	0	0	0	0	0	8	48
Average Number of Cold Days (20° or less, Dec., Jan., and Feb.; 28° or less, Mch., Apr., and Nov.)	7.3	6.2	6.0	0.2	0	0	0	0	0	0	2.8	4.6	27.1

SUMMARY OF AVERAGE AND EXTREME VALUES (1871-1904).—Continued.

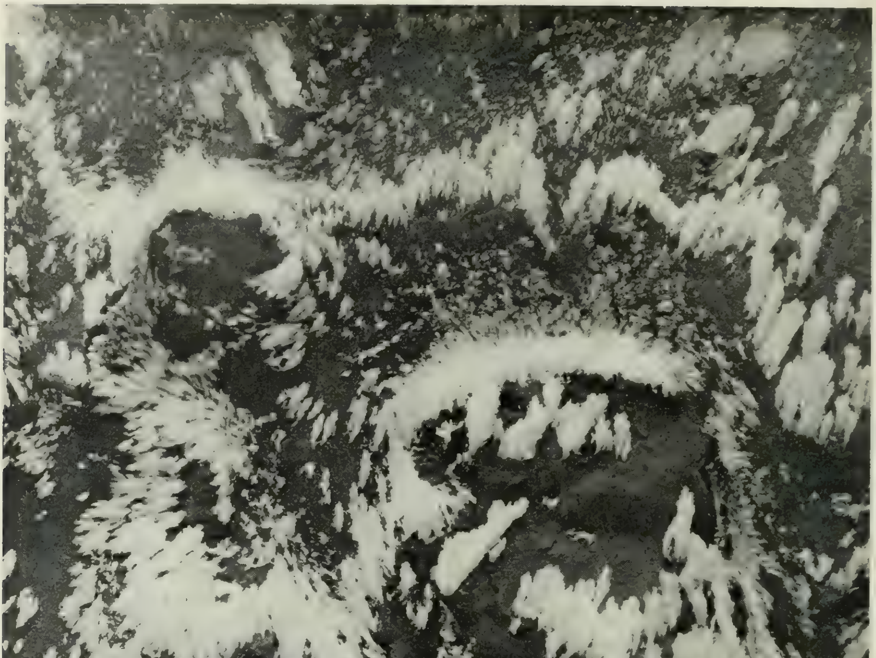
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
II. TEMPERATURE.—Continued.													
Greatest Number of Cold Days	19	18	15	3	..	..	..	..	..	..	11	16	55
Least Number of Cold Days	0	0	0	0	..	..	..	..	..	..	0	0	11
Average Number of Days with Mean Temperature Above 42°	5.3	6.5	14.1	27.0	31.0	30.0	31.0	31.0	30.0	30.6	19.4	8.2	264
Greatest Number of Days with Mean Temperature Above 42°	18	16	29	30	31	30	31	31	30	31	28	23	293
Least Number of Days with Mean Temperature Above 42°	0	0	5	21	31	30	31	31	30	28	12	0	243
Average Number of Days with a Temperature of 90° +	0	0	0	0.1	0.9	4.5	9.3	4.5	1.7	0.03	0	0	21.0
Greatest Number of Days with a Temperature of 90° +	0	0	0	2	7	9	19	17	8	1	0	0	44
Least Number of Days with a Temperature of 90° +	0	0	0	0	0	0	0	0	0	0	0	0	8
Temperature of Water in the Harbor (2 p. m.)	34.8	35.5	40.1	51.4	62.1	73.4	78.3	78.3	74.0	65.2	52.4	39.8	57.1
Frequency of Changes of 0-6° in Daily Mean Temperature	16.7	15.0	16.9	19.0	20.8	22.1	25.4	25.3	22.0	20.0	19.4	17.8	241.0
Frequency of Changes of Over 6° in Daily Mean Temperature	13.6	13.1	13.3	10.9	9.2	7.1	5.0	4.6	7.9	10.0	10.7	12.6	118.9
Frequency of Changes of Over 8° in Daily Mean Temperature	9.3	8.8	9.1	6.1	5.0	3.4	1.9	2.0	4.2	5.7	6.3	8.0	71.0
Frequency of Changes of Over 10° in Daily Mean Temperature	5.8	5.6	5.7	3.5	2.4	1.3	0.7	0.8	2.0	2.9	3.6	5.2	40.6
III. PRECIPITATION (inches and hundredths).													
Mean Monthly Precipitation	3.20	3.70	3.99	3.27	3.63	3.78	4.66	4.20	3.85	2.99	2.99	3.07	43.34
Maximum Monthly Precipitation	6.42	7.07	7.94	8.70	7.26	8.08	11.05	9.49	10.52	6.85	6.85	7.07	62.35
Minimum Monthly Precipitation	0.88	0.65	1.19	1.37	1.00	0.90	1.40	0.64	0.09	0.16	0.65	0.37	31.57
Average Number of Days with Appreciable Precipitation	12	11	13	11	12	10	12	11	9	9	10	11	131
Maximum Number of Days with Appreciable Precipitation	19	19	19	16	21	16	18	21	17	16	16	17	164
Minimum Number of Days with Appreciable Precipitation	4	4	8	4	5	6	7	6	2	2	4	5	104
Probability of Precipitation (%)	39	40	42	37	39	35	37	37	30	31	34	35	35.6
Average Duration of Precipitation (in hours and tenths)	10.00	13.10	10.20	11.00	7.30	4.30	4.00	4.00	6.30	8.30	10.50	10.00	8.20
Greatest Precipitation in 24 Hours	1.95	3.48	3.51	3.58	2.99	4.47	4.02	4.36	4.76	3.42	2.85	2.88	4.76
Maximum Amount of Rainfall in 15 minutes (rate per hour)	1.00	..	1.16	..	3.20	2.80	6.88	4.64	3.60	1.52	..	..	6.88
Maximum Amount of Rainfall in 30 Minutes (rate per hour)	.90	..	.58	..	2.44	1.80	5.38	2.48	2.64	1.34	..	..	5.38
Maximum Rate of Rainfall in 1 Hour	..	..	..	..	..	..	..	..	..	..	..	..	.
Mean Monthly Snowfall	5.6	7.5	5.8	0.8	T	..	..	..	..	T	0.8	3.3	23.8
Maximum Monthly Snowfall	16.6	33.9	25.6	8.0	T	..	..	..	..	T	9.7	17.1	51.1
Minimum Monthly Snowfall	0.1	0	0	0	0	..	..	..	..	0	0	0	4.9

SUMMARY OF AVERAGE AND EXTREME VALUES (1871-1904).—Continued.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
III. PRECIPITATION.—Continued.													
Ratio of Snowfall to Total Monthly and Annual Precipitation (%)	17	18	14	2	..	..	..	..	..	..	3	11	.11
Average Number of Days with Snowfall (.10 inch or more)	3.1	3.4	2.2	0.4	..	..	..	..	..	..	0.7	2.2	.12
Greatest Number of Days with Snowfall (.10 inch or more)	9	12	6	2	..	..	..	..	..	..	4	9	26
Least Number of Days with Snowfall (.10 inch or more)	0	0	0	0	..	..	..	..	..	..	0	0	2
Greatest Snowfall in 24 Hours	7.0	15.5	12.0	8.0	T	..	..	..	..	T	4.5	10.6	15.5
IV. RELATIVE HUMIDITY.													
Mean Monthly Relative Humidity (%)	69.5	66.5	64.9	60.1	63.6	66.6	66.4	69.2	70 4	67.6	65.8	67.2	66.5
Highest Mean Monthly Relative Humidity	76	75	82	69	72	76	77	78	83	80	72	77	70.5
Lowest Mean Monthly Relative Humidity	62	58	54	50	50	60	60	60	63	52	56	57	58.8
Mean Monthly Vapor Tension	.136	.133	.193	.252	.394	.549	.631	.614	.512	.334	.222	.152	.344
V. SUNSHINE.													
Average Number of Hours of Sunshine	4.9	6.4	6.8	7.9	7.7	9.2	9.1	8.6	8.1	6.8	5.5	4.8	7.2
Greatest Number of Hours of Sunshine	6.4	8.4	8.8	11.0	9.7	12.4	12.4	11.0	9.9	8.7	10.0	6.2	8.2
Least Number of Hours of Sunshine	3.7	4.3	5.7	5.5	4.6	6.1	6.0	6.6	6.5	4.8	2.9	3.4	5.5
VI. CLOUDINESS.													
Average Amount of Cloudiness (scale of 1-10)	5.9	5.0	5.3	5.7	5.8	5.1	4.9	4.6	4.3	5.0	4.9	5.0	5.1
Average Number of Clear Days	8.3	8.4	8.8	9.2	9.5	9.0	10.0	10.7	11.9	12.4	10.2	9.7	118.1
Greatest Number of Clear Days	15	15	14	17	15	17	19	19	22	23	16	16	166
Least Number of Clear Days	4	3	4	4	3	2	2	2	6	7	2	4	84
Average Number of Partly Cloudy Days	12.1	10.9	11.5	11.8	11.6	14.0	13.3	12.9	10.5	10.2	10.2	11.5	140.5
Greatest Number of Partly Cloudy Days	18	18	18	17	19	25	21	17	19	16	19	20	182
Least Number of Partly Cloudy Days	5	4	5	3	5	6	9	6	4	4	6	5	111
Average Number of Cloudy Days	10.6	8.9	10.7	9.1	9.9	7.3	7.4	7.4	7.5	8.7	9.6	9.4	106.6
Greatest Number of Cloudy Days	16	16	16	18	17	16	14	17	15	15	16	18	138
Least Number of Cloudy Days	3	2	5	2	4	1	3	2	0	0	4	5	81

SUMMARY OF AVERAGE AND EXTREME VALUES (1871-1904).—Continued.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
VII. WINDS.													
Average Daily Wind Movement	145	162	175	166	149	142	134	122	129	137	143	142	145
Maximum Daily Wind Movement	210	253	259	220	213	188	177	142	171	201	219	201	192
Minimum Daily Wind Movement	89	95	128	119	118	109	108	94	106	99	104	95	122
Maximum Velocity (miles per hour)	48	45	50	60	43	42	70	45	38	45	48	54	70
Frequency of Velocities of 0-10 Miles per Hour (%)	73.3	66.4	70.1	69.5	78.3	85.9	87.4	88.7	83.8	79.4	74.9	76.0	77.9
Frequency of Velocities of 11-20 Miles per Hour (%)	22.2	25.6	24.5	28.1	20.5	14.0	12.1	10.4	15.7	18.4	22.6	22.0	19.7
Frequency of Velocities of 21-40 Miles per Hour (%)	4.3	7.9	5.2	2.4	1.2	0.1	0.2	0.6	0.7	2.1	2.6	1.9	2.3
Frequency of Velocities of Over 40 Miles per Hour (%)	0.03	.00	0.03	.00	.00	.00	.00	.00	.00	.00	.00	.00	0.005
Average Duration of Storm Winds (in hours and minutes)	3.50	4.40	3.40	2.30	1.20	0.12	0.20	3.00	1.25	2.40	2.00	3.00	2.50
Prevailing Direction of Winds	NW	NW	NW	NW	SE	SW	SW	SW	N	NW	NW	NW	NW
Prevailing Direction of Lower Clouds 7 a. m.	SW NW	NE	NW	NW	W	W	W	W	W	W	W	W	W
Prevailing Direction of Lower Clouds 3 p. m.	W	NW	W	NW	NW	W NW	NW	W	W	NW	NW	NW	NW
Prevailing Direction of Upper Clouds 7 a. m.	W	W	W	W	W	W	W	W	W	W	W	W	W
Prevailing Direction of Upper Clouds 3 p. m.	W	W	W	NW	W	W	W	W	W	W	W	W	W
Relative Frequency of Stated Wind Directions (%)	..	..	..	..	..	..	..	..	..	..	..	.	..
N	12	..	..	6	..	..	11	..	..	18	..	..	12
NE	7	..	..	8	..	..	3	..	..	7	..	..	6
E	13	..	..	10	..	..	5	..	..	11	..	..	10
SE	11	..	..	31	..	..	14	..	..	14	..	..	17
S	2	..	..	2	..	..	9	..	..	6	..	..	5
SW	13	..	..	14	..	..	30	..	..	13	..	..	17
W	23	..	..	14	..	..	14	..	..	12	..	..	16
NW	19	..	..	15	..	..	14	..	..	19	..	..	17
VIII. THUNDERSTORMS.													
Mean Monthly Thunderstorm Frequency	0.1	0.4	0.7	1.2	3.8	5.6	6.4	4.0	1.5	0.2	0.2	0.1	24.2
Maximum Monthly Thunderstorm Frequency	1	2	4	6	8	11	15	10	5	2	2	1	46
Minimum Monthly Thunderstorm Frequency	0	0	0	0	0	1	1	0	0	0	0	0	8
Total Hail Frequency in 28 Years	4	3	3	3	11	13	9	6	1	0	1	1	55



FROST FIGURES FORMED ON STONE COLUMN OF MT. WEATHER OBSERVATORY BUILDING,
DURING ICE-STORM OF MARCH, 1906.
(PHOTOGRAPH BY E. R. MILLER U. S. WEATHER BUREAU.)

THE WEATHER OF BALTIMORE

INTRODUCTION

Leaving now the discussion of *climate,* or the average and extreme values of the principal factors which constitute the sum total of atmospheric conditions, we come to a consideration of some of the more important types of *weather* characteristic of the geographical horizon of Baltimore. As stated in the introduction to this report, the term *weather* is restricted in its use to the *actual* state of the atmosphere as regards temperature, humidity, wind movement, etc., at any given instant, or short period of time. The method employed in the discussion of climatic conditions is not applicable to descriptions of weather; the various factors cannot be considered separately, but must be studied in their relations to one another at a given instant of time, in order to afford a proper mental picture of actual conditions in nature.

The past fifty or sixty years have witnessed a gradual but radical change in our views of weather conditions and sequences. Before the days of the telegraph, observers were isolated and independent of one another; we had but vague ideas as to synchronous weather conditions prevailing at distant points. Here and there in the eighteenth century we find a suggestion of the importance of co-operation in the methods and time of making observations; but intercommunication was slow and the important discoveries of Franklin and Jefferson in America, of Brandes in Germany, and others, met with rather tardy recognition, or were entirely overlooked and had to be rediscovered when times were more propitious for utilizing the results of new discoveries.

The rich collection of weather proverbs, based upon natural signs—changes in the wind, forms of clouds, the habits of animals—are based upon the accumulated experience of individual effort. For centuries

weather changes were minutely observed and carefully recorded. Especially was this true of changes in wind direction, as this factor was almost universally regarded as the underlying cause of variations in the other elements. Not until the use of the telegraph became general, making it possible to gather reports from an area covering thousands of square miles, and to obtain a picture of actual weather conditions at the same instant of time over this area, was the true meaning of weather changes gradually revealed to the student of meteorology. Change in the direction of the wind, while it still holds a conspicuous place in weather prognostics, is no longer regarded as the fundamental factor in the weather situation. The weather map, so familiar to us to-day, shows us that atmospheric pressure, or the height of the barometer, is the key to the problem of coming weather—not the actual height of the barometer at a single station, or at a number of stations, but the relative heights over a large area. Having given the relative distribution of pressure over a given area, the remaining weather elements can be supplied with a fair degree of accuracy by the expert student in weather forecasting.

The Synoptic Weather Chart.

The development of the synoptic weather chart, a chart showing the actual physical condition of the atmosphere at the same hour over an area of thousands of square miles, forms one of the most interesting chapters in the history of modern meteorology. Conceived before the close of the first quarter of the nineteenth century, the middle of the century witnessed a remarkably rapid development and application of the idea. This was brought about by the rapid spread of the electric telegraph and the recognition of the vast commercial importance of such a chart. The successive steps of its progressive development in this country and in Europe have been carefully traced by Abbe[1] and Hellmann,[2] to whom we are indebted for much of our accurate history of meteorology.

[1] Abbe, Cleveland. The Development of the Daily Weather Map. Vol. I, Maryland Weather Service, Baltimore, 1899, pp. 225 *et seq.*

[2] Hellmann, G. Neudrucke von Schriften und Karten über Meteorologie und Erdmagnetismus. No. 8, Berlin, 1897.

To-day the great majority of the nations of the world support a national weather service and issue such charts daily. We now have daily charts of synchronous observations for most of the land area of the northern hemisphere excepting Asiatic Russia and China; and of the North Atlantic. In the southern hemisphere, there are charts for Australia, the Indian Ocean, South Africa, and the Argentine Republic. The time will soon come for the realization of one of the fondest hopes of the meteorologist, when we shall be able to construct such maps for practically the entire globe. The importance of the constant endeavor to extend the area of observations becomes apparent when we realize that there are no definite boundaries in the atmosphere of the globe, and that no extensive disturbance can take place in any portion of its vast extent without affecting, sooner or later, every other portion. We probably do not yet realize fully the nice adjustment of atmospheric forces, and we are still ignorant of many of the important laws underlying the larger atmospheric movements.

Cyclones and Anti-cyclones.

Before the advent of the synoptic weather chart, the constant changes in the direction of the wind, the increase and decrease in cloudiness, the occurrence of rain with a certain wind and clear skies with another, were very little understood. Certain sequences in weather changes had long been accurately noted, but why these changes should follow a definite order was incomprehensible. The weather map, however, revealed the clue to the interpretation of the changes in the relative distribution of atmospheric pressure over extended areas. It was soon learned that differences of pressure, or of the height of the barometer in neighboring localities, set the air in motion, causing it to flow from the area of high barometric pressure to the areas of lower barometric pressure, much as water is transferred from a higher to a lower level. This flow of the air from place to place in an effort to restore a disturbed equilibrium is what is termed the wind. Changes in wind direction in turn bring about changes in temperature, the wind blowing warmer with a change from a northerly to a southerly direction in the northern hemisphere, with inter-

mediate changes in temperature when blowing from the east or west. A study of the weather map soon led to the formulation of a new set of rules of weather changes, more general in their application and more intelligible than those based on the study of observations at a single station. Two distinct types of weather were soon recognized. The most conspicuous of these, and the first to be investigated was the storm area, an area in which the readings of the barometer decrease rapidly from all sides *to a minimum in the center* of the area. Such areas were observed to be accompanied by cloudy skies, and more or less rain, by winds increasing in force as the center was approached, and blowing approximately toward the point where the barometric pressure was lowest. As the types of weather first investigated were naturally well developed storm areas, the winds high and blowing in paths nearly circular, or at least spirally inward, the term *cyclone* was applied to them; a term first used about the middle of the nineteenth century by Captain Henry Piddington to describe revolving storms in the Indian seas. Later, the term *cyclone* was given to all atmospheric disturbances of wide area in which the winds blow toward a central point or line of low pressure.

Another weather type which later claimed the attention of students of meteorology was the fine weather type, in which the barometric pressure is highest in the central area, *decreasing in all directions from the center outward.* In these areas the winds were observed to blow in general away from the center of highest pressure. As the characteristics of these areas were in many respects the opposite of those observed in cyclones, they were given the name *anti-cyclones.*

Between these two well defined types, there are innumerable forms partaking more or less of the characteristics of one or the other of the two principal types.

In the northern and southern hemispheres, from latitude 30° to 70°, the upper portions of the atmosphere apparently flow in a constant stream in a direction approximately from west to east around the globe. The winds within the lower layers of the atmosphere in the middle latitudes do not always follow the course of the upper currents; the atmosphere from the earth's surface to the level of the highest clouds is broken

up into areas in which the barometer is alternately low and high, into cyclones and anti-cyclones, as they are generally designated. These alternate areas of unsettled weather and fine weather are carried along as a whole in an easterly direction with the general drift of the upper atmosphere, constantly changing in form and intensity as they move, but retaining, in the main, their chief characteristics for thousands of miles; the areas of high pressure are accompanied by comparatively little cloudiness, and temperatures below the seasonal average; while the areas of low pressure are attended by clouds and rain and a temperature above the seasonal average. These cyclonic and anti-cyclonic areas of the middle latitudes have a diameter varying from a few hundred to a thousand, or even two thousand, miles and move eastward, as a whole, with a velocity averaging about 600 miles per day, across the United States, and hence occupy two or three days in passing a fixed point. Their passage eastward explains the constant shifting in the direction of the winds of a given locality, the direction of the change in wind, as will be explained later, depending upon the position of the center of the anti-cyclones and cyclones with reference to the given locality. For instance, when a "low," or cyclonic area, approaches Baltimore from the west, if the center is north of the latitude of Baltimore, the wind becomes easterly; as the center passes Baltimore, the wind shifts to the south, and then to the west or northwest. If the center of the storm passes to the south of the city, the changes in the wind direction are successively, east, north, and west, the reverse of those in the first case cited. If the center passes over Baltimore, the easterly wind is followed by a calm, or light variable wind, after which the wind will spring up abruptly from the west.

These rules of weather sequences are applicable only to the well developed and definitely formed areas of high and low pressure, and but imperfectly apply to the more numerous moderately developed "highs" and "lows" whose eastward drift gives us our daily routine of weather changes.

A clear conception of the character of cyclones and anti-cyclones, as described above—of the distribution of pressure, the system of winds, the distribution of temperature, the state of the weather, and the move-

ments of these areas, as a whole—is essential to a proper understanding of our daily weather changes, and especially of the more conspicuous weather types known as storms and cold waves. The essential features of cyclones and anti-cyclones may be most readily understood by a study of actual examples of the simpler well developed types. As an illustration of a typical storm or cyclone, the weather chart of the morning of December 27, 1904, is reproduced in Figs. 85, 86. To those unfamiliar with the weather map—and indeed to all excepting those who have devoted much time to their study—the usual weather map is a confused tangle of lines and symbols requiring careful explanation and analysis before even the essential features of the weather conditions are understood. Some of these difficulties may be obviated by the use of a series of charts portraying the separate factors which go to make up the complex weather conditions, retaining in each chart, however, the controlling factor, namely, the system of lines representing the distribution of atmospheric pressure, or isobars, as they are called.

AREAS OF UNSETTLED WEATHER (CYCLONES).

It may be well at this point to call attention to the very frequent misuse of the terms *cyclone* and *tornado*. In scientific literature there is a clear distinction between the two, while in the popular mind, they are often synonymous. The confusion in the use of these terms is natural, and is largely due to a change in the meaning of the word "cyclone" as used in technical literature. A cyclone has at all times, since the days of Piddington (about 1850), been regarded as a severe and destructive storm. Later when the nature of storms and weather changes was better understood, the meaning of the term was enlarged by the student of meteorology to include all atmospheric disturbances, whether large or small, intense or barely perceptible, in which the winds blow inward toward a central point, or area of low barometric pressure. The general public has not yet adopted this amended definition, and all intense storms continue to be called cyclones, when the particular storm in mind may be a tornado, squall, an intense thunderstorm, or a hurricane. While the tornado, as a revolving storm, must be classed with cyclones, the

LEGEND.

The following explanation applies to U. S. daily weather charts reproduced in this report. The charts are based on simultaneous observations made at 8 a. m., 75th meridian time.

Black lines are lines of equal temperature (in degrees Fahr.).

Red lines are lines of equal atmospheric pressure (in inches).

Shaded areas mark the limits of overcast skies.

The arrows fly with the wind.

R indicates rain.

S indicates snow.

T indicates the occurrence of a thunderstorm during the preceding 12 hours.

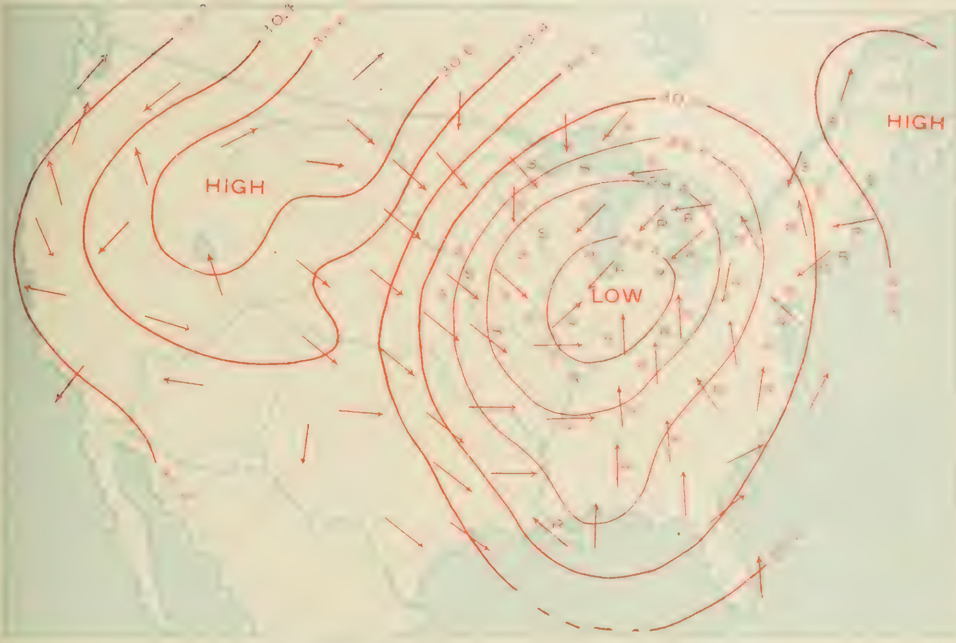


Fig. 85.—Typical Cyclone of December 27, 1904.

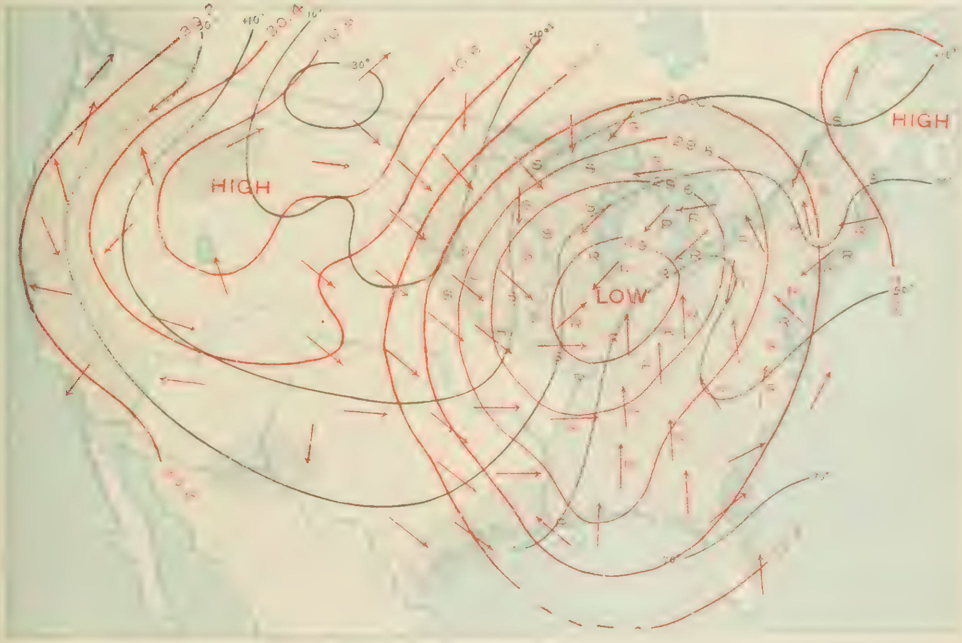


Fig. 86.—Typical Cyclone of December 27, 1904.

term is restricted to the intense and very destructive local storms of very small area occurring within certain limited portions of a larger storm; it is a cyclone within a cyclone.

The accompanying charts, Figs. 85 and 86, show the distribution of pressure, wind direction, temperature, cloudiness, and precipitation, within the area of the typical cyclone which passed over the United States during December 27, 1904.

Pressure and Winds.—The series of red curved lines show the distribution of atmospheric pressure. The inner, nearly circular, line enclosing the word "low" in the chart for December 27 is drawn through localities in which the barometer read 29.40 inches, the lowest reported pressure. The remaining curves connect localities in which the barometer stood higher by successive intervals of two-tenths of an inch, until around the outer limits, at approximately a thousand miles from the center, the barometer read 30.40 inches, showing a difference in pressure of one inch.

The atmosphere is very responsive to local differences of pressure. With very slight differences, a small fraction of an inch, for example, there will be set up a movement of air from the locality having the higher toward that having the lower reading of the barometer until equilibrium is restored, for the same reason that water always has a tendency to flow from a higher to a lower level. Bearing in mind this general physical law of the flow of gases, we may understand the general drift of the atmosphere toward the central area of low pressure in a cyclone. This is clearly shown by the arrows which indicate the direction of the wind at so many stations of observation; the arrows fly with the wind and point in a general way toward the area of lowest pressure. As will be observed they only occasionally point directly toward the center; in most instances the direction taken by a particle of the atmosphere in its journey from the outer portion of a storm area toward the center is along a spiral course. This is due to the effect of the rotation of the earth about its axis, which always tends to urge a freely moving particle toward the right of its initial direction, in the northern hemisphere. The topography of the region over which the storm passes, and more

important still, the distribution of the pressure about the central area as shown by the curved lines, or isobars, also greatly influence the direction of the wind. In general, and especially over land areas, the isobars vary widely from the circular form, and the actual wind directions fall roughly into two classes, easterly and westerly. Drawing a north and south line through the center of the cyclone, the winds to the east are observed to flow mostly from some point between northeast and southeast, while those to the west of the line blow mostly from some point between southwest and northwest. The winds blowing directly from the south or from the north are not so frequent, or of as long duration as those from other directions. The effect of pressure distribution on the direction and force of the wind will be brought out very clearly in later discussions of weather types. In general, it may be stated that the force of the wind is greater the greater the difference of pressure between two neighboring points; that is, it is proportional to what is called "the gradient," which is equivalent to difference of level in the flow of streams; the steeper the bed of the stream, the more rapid is the flow of water.

Temperature and Wind Direction.—Especial attention is directed to the relation existing between wind direction and temperature in a cyclone. Localities reporting the same temperature at 8 a. m. are joined by means of lines, or isotherms, as they are styled. The lines are drawn at intervals of 10° or 20° Fahr. It will be observed that the temperature of 70° above zero in lower Florida gradually diminishes, as we proceed northward, to 30° below zero in the extreme northern limits. This is the usual direction of decrease in temperature at all seasons of the year, though the rate of decrease is here much more rapid than under normal conditions. In the absence of a well defined atmospheric disturbance the isotherms run nearly parallel with the lines of latitude; a steady and fairly uniform decrease in temperature from south to north is the normal condition all over the northern hemisphere. The relative temperature of winds from different quarters may vary greatly in different localities, but in the main, a southerly wind is warmest and a northerly wind coldest, with intermediate degrees for the east and the west wind. Hence we may readily understand how a change in the direction of the wind

may affect the temperature of a locality. On the approach of a cyclone, in most cases from the west, the winds to the east of the center become easterly, veering to southerly; the temperature rises in the eastern half of the storm, and particularly in the southeast quadrant where the winds are from southeast or south. In the southwest quadrant of the storm there is usually an abrupt change from the warm south or southeast wind to a much colder west or northwest wind. This condition of temperature distribution is strikingly exhibited in the charts. The isotherms are seen to bend northward far beyond their seasonal values in the southeast quadrant; on the other hand, in the southwest quadrant, the cold northwest winds are carried far beyond their normal limits to the southward. The result is a stronger contrast in temperature from the center of the storm westward than from south to north; the isotherms run north and south, in the particular case cited, and not east and west as in normal weather conditions. These shifts in the direction of the wind during the passage of a cyclone are sufficient cause for the great majority of the temperature changes experienced in our latitudes.

Distribution of Clouds and Precipitation.—The proportion of the area covered by clouds at 8 a. m. is indicated by the extent and intensity of the shading. It will be observed that in practically all of the region within the influence of the system of closed isobars, the skies were entirely overcast, and that over an area extending 500 to 600 miles in nearly all directions from the central point of lowest pressure, precipitation occurred at the hour of observation—rain to the south of the isotherm of 30° and snow north of this line. The area of precipitation in this particular storm was exceptional, but it serves to illustrate the general law of the distribution in well developed storms of large extent. In most cases the area of precipitation is more limited in extent and is surrounded by a band of overcast skies, beyond which is a partly clouded band merging into regions of clear skies. Not all cyclones, even when well developed, show the symmetry in the distribution of weather conditions indicated in the type selected; the variations are infinite, but there is a general conformity to the type when the storm is well developed. The center of the rain or snow area is usually to the east and south of

the center of low pressure. The details of the distribution and the character of the precipitation will be brought out more clearly in the later discussions of weather types of the season.

The elements described separately in the preceding pages are finally brought together upon a single chart, the usual form of presenting in our daily weather charts the actual condition of the weather at a stated hour. Such charts, showing the actual state of the weather at 8 a. m. throughout the United States and the British Provinces to the north, are issued daily about 11 a. m. by the United States Weather Bureau, based on telegraphic reports from about 175 stations.

AREAS OF FAIR WEATHER (ANTI-CYCLONES).

As already stated in a preceding paragraph, the term *anti-cyclone* was first used to describe a weather type which shows characteristics just the opposite of those of the *cyclones.* The pressure is *highest* in the centre of the area, the winds blow in a general direction *away* from the center, the skies are mostly clear to partly clouded, with little or no precipitation, the temperatures are, in general, *lower* at the center than on the eastern or western sides of the area; that is, their isotherms curve southward toward the center of high pressure while those in the cyclone bend northward toward the central area of low pressure.

A typical example of an anti-cyclonic system is shown in the weather map of April 4, 1904, reproduced in Figs. 87, 88. It occupied approximately the same position and covered the same area as did the cyclone of December 27, 1904, shown in Figs. 85, 86.

Isobars and Winds.—The inner circle, or isobar of 30.60 inches, marks the central area of the anti-cyclonic system, from which there is a steady and uniform decrease in the height of the barometer outward in all directions, the successive isobars marking intervals of two-tenths of an inch in the height of the barometer, as in the case of the cyclonic system described above. It will be observed that the gradient, or steepness of the successive steps between isobars, is less in the anti-cyclone than in the cyclone; the area covered by each system is approximately the same, while the total difference in pressure between the center

Fig. 87.—Typical Anti-cyclone of April 4, 1904.

Fig. 88.—Typical Anti-cyclone of April 4, 1904.

LEGEND.

The following explanation applies to U. S. daily weather charts reproduced in this report. The charts are based on simultaneous observations made at 8 a. m., 75th meridian time.

Black lines are lines of equal temperature (in degrees Fahr.).

Red lines are lines of equal atmospheric pressure (in inches).

Shaded areas mark the limits of overcast skies.

The arrows fly with the wind.

R indicates rain.

S indicates snow.

T indicates the occurrence of a thunderstorm during the preceding 12 hours.

and outer circumference in the case of the anti-cyclone is only half that in the cyclone, namely, one-half an inch. This is also shown by the number of the isobars, the cyclone having double the number shown in the anti-cyclone, while the successive steps of increase or decrease in pressure, and the entire areas covered by the two systems are the same. This is characteristic of the two types, though the proportions may vary greatly. The winds are observed to blow in a general direction away from the center. As the winds in an anti-cyclone are in general much lighter in force than in a cyclone, the actual directions recorded near the surface are influenced to a greater extent by local topography. This is especially marked near the center of the area where the winds are very light.

The law of deviation of a particle of air to the right of the initial direction flowing from the center of the high area outward holds good, as noted in the discussion of the inward flow in cyclones; hence the arrows, indicating the direction of the wind in the anti-cyclone, are observed to point, not directly from the center but to the right of the radial path, the angular deviation depending upon the configuration of the isobars, the topography and other factors.

The Winds and Distribution of Temperature. Especial attention is directed to the relation between wind direction and temperature. Here again, as in the case of the cyclone, the temperature is seen to be directly dependent upon wind direction. In those portions of the area where the winds are mostly from a warm southerly direction, particularly noticeable in the northwest quadrant in the illustration shown, the isotherms are bent far northward of their normal position for the season. In the northeast quadrant of the area, where the winds are mostly from the colder north, the isotherm of 30° is seen to dip far to the south. Along the Atlantic coast the cold of the northerly wind is considerably tempered by the presence of the ocean, over which the rate of change in temperature is much less marked than on land along a north and south line.

In the center of a "high," another factor enters to lower the temperature below the normal for the season. Here the skies are clear and

radiation from the surface of the earth is rapid. This is especially true during the night hours and, in consequence, the effect is quite marked on a chart based on observations made at 8 a. m., before the heating effect of the rising sun becomes marked. As a result of the conditions described, the lowest temperatures in a well developed anti-cyclone are generally observed to be within the central isobar of a system, if measured by departures from the normal seasonal values for a given locality.

Distribution of Clouds.—The chart selected as an example of an anti-cyclone shows almost too well one of the characteristic features of this type of weather, namely, the absence of clouds. While freedom from precipitation and clouds is the most striking difference between a cyclone and an anti-cyclone, it is not usual to see a weather chart with a high area of so great an extent with skies practically free from clouds, as is here shown. Over an area embracing all the states and the Canadian Provinces, from the Mississippi Valley eastward to the Atlantic coast, an overcast sky was reported at 8 a. m. from only four or five observing stations. Usually, even in the well defined and well developed areas of high pressure there is a fair percentage of cloudiness, excepting within a radius of two hundred or three hundred miles from the center.

The presumption is that this freedom from clouds and precipitation in an anti-cyclone is due to a descending atmosphere, with attendant increase of temperature, due to compression and consequent decrease in the relative humidity; the opposite process, namely, a rising atmosphere cooled by expansion, accompanied by an increasing relative humidity and by cloud formation, and later by rain or snow, marks the cyclone.

THE EASTWARD DRIFT OF CYCLONES AND ANTI-CYCLONES.

In describing the distribution of pressure, winds, temperature, and clouds in typical cyclones and anti-cyclones in the preceding paragraphs no reference was made to their movement as a whole. The systems are not stationary for any length of time. In addition to the internal circulation of the winds described, the entire systems are carried eastward by the general drift of the upper atmosphere in the middle latitudes, retaining at the same time their chief characteristics as cyclones

and anti-cyclones for many hundreds, and sometimes thousands of miles. The small whirls formed in a rapidly flowing river and carried down stream with the general current, while at the same time maintaining their own gyratory motion, are often cited as illustrations of the drift of cyclones and anti-cyclones in the general eastward flow of the atmosphere between the parallels of 30° and 70° north and south latitude. These "highs" and "lows" do not extend to a great altitude, but are

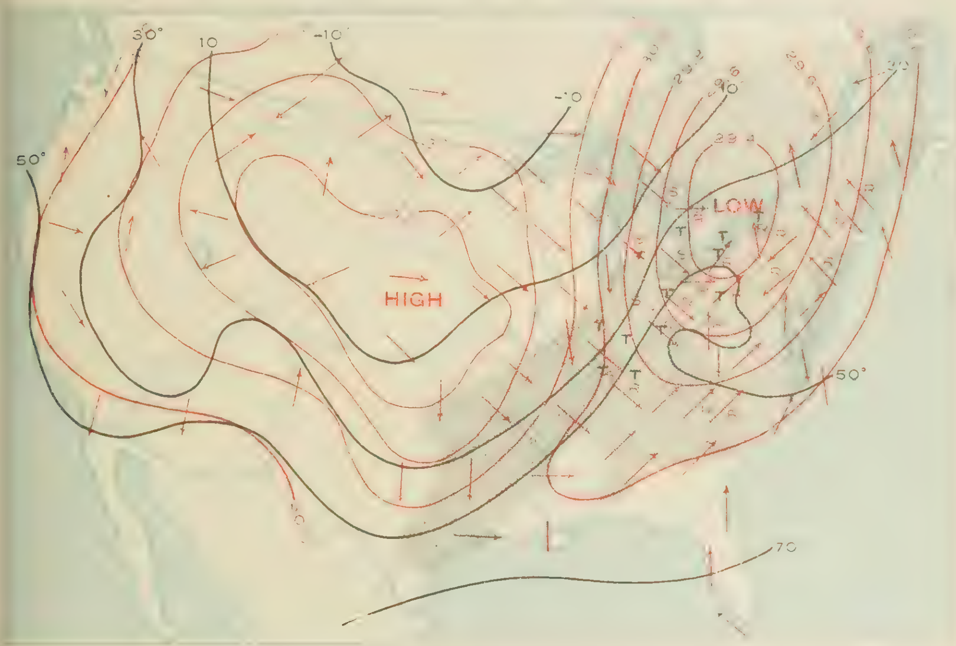


FIG. 89.—Typical Cyclone and Anti-cyclone of March 3, 1904.

formed apparently only in the lower portions of the atmosphere, the great majority of them being confined to the atmospheric strata below the highest mountain ranges. They are carried in an easterly direction in the middle latitudes with a varying velocity but averaging about 600 miles per day, while moving across the United States. There is a constant and rapid succession of these atmospheric whirls, or waves of high and low pressure, in the winter and spring season. In summer and early fall they are less frequent and not so well developed. There is

an excellent example of a well developed "low" or cyclone, followed by a "high" or anti-cyclone in the chart for March 3, 1904. (Fig. 89.)

The shifts in the direction of the wind experienced during the passage of these "lows" and "highs" may be illustrated upon this chart by noting the directions of the wind at points along a given parallel of latitude passing from east to west. The nature of the change of wind depends upon the position of the center of the cyclone or anti-cyclone with reference to the parallel selected. Taking the latitude of 40° for example in the chart for March 3, 1904, we have, as we pass westward from the Atlantic seaboard, first a southeast wind followed by a small area of south wind, in West Virginia, followed by a northwest wind to the center of the succeeding "high" in western Nebraska. To the west of the center of the anti-cyclone we have again a southerly wind in Colorado and Utah. Selecting a parallel of latitude north of the center of the "low" and "high," we have a reversed order in the shift of the wind. In the "low" the change is from easterly to westerly by way of the north; and in the "high" from westerly to easterly by way of the south.

Similar shifts in the wind are experienced in a fixed locality, such as Baltimore, for example, as these cyclones and anti-cyclones approach and pass beyond the observing station. An easterly wind at Baltimore heralds the approach from the west or southwest of a more or less developed cyclone, or storm area, followed by increasing cloudiness and rain or snow, as the center of the storm approaches. After the wind veers to the south and then to the southwest the precipitation soon ceases, the solid cloud mass begins to break into patches of cloud and, as the wind gets into the west, the proportion of clear sky increases until the cyclonic system passes beyond the horizon in the east. This is the usual order of change. With the path of the storm center to the south of Baltimore, the wind backs from east to west by way of the north.

The weather types described above are of unusual symmetry. The forms met with in our daily routine of weather conditions are infinite in variety. No two are exactly alike in all their details of pressure, temperature and cloud distribution, or in the paths pursued, but there are many easily recognizable types with marked family resemblances which are of great

assistance to the practical meteorologist engaged in weather forecasting. Some of these types will be discussed in detail in the following pages.

WEATHER CHARTS OF THE NORTHERN HEMISPHERE.

A remarkable series of daily weather charts covering a period of ten years was prepared and the results published under the auspices of the

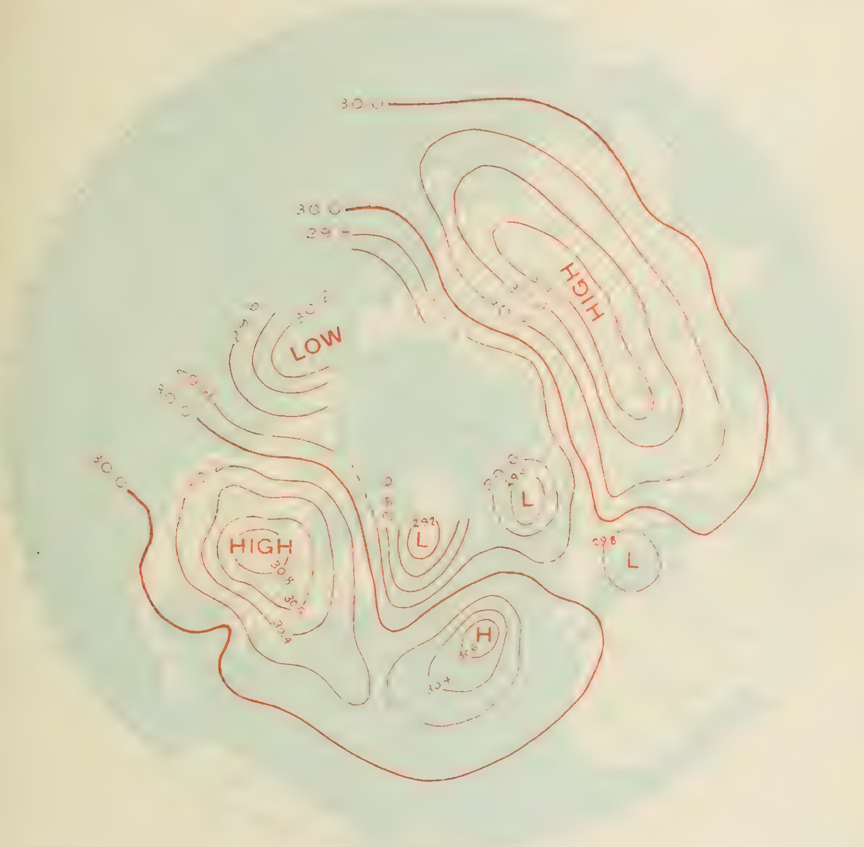


Fig. 90.—Pressure Distribution over the Northern Hemisphere, Dec. 4, 1886.

United States Weather Bureau, then known as the Signal Service, from 1878 to 1887. The charts were based on reports received from co-operating national weather services and covered the whole of the northern hemisphere between the latitudes of about 20° to 65°, excepting the

Pacific Ocean. One of these charts, showing the actual distribution of pressure at noon, Greenwich time, for December 4, 1886, is reproduced in Fig. 90. The chart shows clearly the manner in which the lower atmosphere of the middle latitudes is segregated into successive areas of low and high pressure, or cyclones and anti-cyclones at a given hour.

Weather of the Principal Climatic Zones.

It has been customary for convenience to divide the surface of the globe into three climatic zones, the tropical, the temperate, and the polar, separated by fixed parallels of latitude and based upon the altitude of the sun above the horizon. The climatic conditions experienced within these zones have no such definite boundaries. When we come to the question of daily weather conditions, it is even more difficult to assign any fixed limits to areas of characteristic weather types. Still, it is possible to designate a number of zones, in the central portions of which the weather conditions are sharply marked off from conditions in neighboring zones.

THE TROPICAL ZONE.

The climatic belt designated as the tropical zone has several sub-zones of characteristic types of weather. The entire zone is marked by a uniformly high temperature, but the moisture conditions and atmospheric movements vary greatly in neighboring regions. The temperature changes from day to day, or from season to season being very small, the seasons are marked by a varying frequency or quantity of rainfall, or by a change in the direction of the wind. One day is very much like another the year round, and the weather cycle is the daily cycle, offering a strong contrast with the rapid fluctuations experienced in more northern latitudes.

The doldrums, or equatorial calms, are characterized by high temperature and humidity, light winds or calms, much cloudiness and frequent and heavy rains, and almost daily thunderstorms—a combination causing an oppressive and debilitating atmosphere.

To the north and south of the doldrums are the trade wind belts. Here the skies are mostly clear, while a fresh, dry, northeast or southwest wind, strongest over the ocean, blows steadily toward the equatorial belt of highest mean temperature.

Beyond the northeast and southeast trades, there is another belt of light winds or calms, the so-called "horse" latitudes; these are areas of permanently high pressure, clear skies and warm dry air, resembling in many respects the summer anti-cyclone of the middle latitudes. Within this belt most of the great desert areas of the earth are found, in the southern as well as the northern hemisphere.

The moving cyclones and anti-cyclones, described in preceding pages as characteristic of temperate zone weather, are conspicuous by their absence in most portions of the hot zone. In some portions, notably in the West Indies, the Philippines, and the Indian seas, cyclones of great intensity occur during the late summer and early fall, the well-known hurricanes and typhoons, which are carried in a westerly direction by the general drift of the atmosphere in the equatorial regions; but they are of infrequent occurrence when compared with the constant succession of temperate region cyclones.

THE TEMPERATE ZONES.

In the middle latitudes, north and south of the equator and extending beyond the Arctic and Antarctic circles, the weather is completely dominated by the moving cyclones and anti-cyclones described in preceding paragraphs. Here the daily monotony of tropical weather is replaced by great variability of temperature conditions which mark the seasons, and by the more rapid fluctuations which accompany the passing of cyclones and anti-cyclones. Tropical heat succeeds polar cold and all the weathers of the globe are brought to our doors during the course of a year. These contrasts become more and more marked as we approach the central portions of the great continental areas of the northern hemisphere. In the extreme northwest of our own country and in the British northwest territory, the breeding ground of cyclones and anti-cyclones, the contrasts in temperature experienced at a single station within a few hours, or

within very limited areas at the same hour, are sometimes marvelous. On the 10th of February in the year 1899, an anti-cyclone developed over Montana and the British territory just beyond. It spread rapidly over the United States as one of the most intense cold waves ever experienced in this country, lowering the record of intense cold in many states in its progress southeastward to the Gulf of Mexico and the Atlantic coast. On the morning of the 10th a minimum temperature of 65° below zero was registered in the western part of Montana. Just west of the mountains in the neighboring state of Washington, the temperature at the same hour was 63° above zero, a difference of 128° between two points along the same parallel of latitude (50° north) less than 300 miles apart.

The southeastward progress across the United States of some of the more marked cold waves is frequently attended by strong inversions in the normal distribution of temperature along the Atlantic coast. The front of the cold wave, with its cold northwest winds, may reach Florida from 12 to 24 hours before it is felt in New England and the British maritime provinces, which may be in the center of the well developed cyclone which frequently precedes the cold wave. Under such conditions, a strong southerly wind will blow along the north Atlantic coast and raise the temperature high above its normal seasonal value for these coasts, while the Gulf states are dominated by the intensely cold northwest wind of the anti-cyclone. In such cases, temperatures of 20° above zero or less are experienced in northern Florida while the warm southerly winds blowing over Newfoundland raise the temperature to 40° or 50° above, although the latter region is nearly 25° of latitude farther north than Florida.

THE POLAR ZONES.

While we are less familiar with the weather conditions of the extreme north and south portions of the globe than with those of the hot and temperate zones, we have abundant evidence that within the Arctic and Antarctic the passing cyclone controls conditions to the highest latitudes attained. The fluctuations in temperature are very great, with changes

in the direction of the wind, while the cold is usually intense. While there are apparently bright, clear and exhilarating days, the weather is mostly gloomy with a high humidity and frequent fogs, sleet and snow. The intense cold weakens the powers of resistance. With these disagreeable weather conditions predominating there is the added gloom of long-continued darkness, the physiological effects of which are exceedingly distressing.

THE SEASONS.

In the middle latitudes, and particularly over the continental areas, the most conspicuous feature of the advance and retreat of the seasons is the marked rise or fall in the mean temperature from month to month. Take, for example, the annual rise and fall of the thermometer at Baltimore as shown by Fig. 25 on page 111; the curves b, c, and d are based on the mean monthly maximum, the normal monthly average and the mean monthly minimum temperatures respectively. The lowest temperatures occur in the months of January and February; from this portion of the curve there is a steady rise at a fairly uniform rate to the month of July, followed by an uninterrupted fall to midwinter. The smooth, simple curve represents a uniform increase and decrease in the power of the solar rays as the sun increases and decreases in altitude in the annual revolution of the earth about the sun. This uniform increase and decrease throughout the year is still shown by constructing the annual curve from the mean temperatures of successive five-day periods. (See Table XVIII, page 89.) If, however, we represent the advance and retreat of the seasons by curves based on *mean daily* temperatures in place of *mean monthly* temperatures, we find a striking difference in the character of the two sets of curves, as is clearly shown by consulting Plate III. There is no such uniformity in the daily progress of temperature; the serrated appearance of the curve indicates clearly that the progress is marked by successive temperature waves having an average period of three or four days. The annual curve is broken up into a series of subsidiary curves of short but irregular periods, due to the constant succession of cyclones and anti-cyclones with their accompanying large fluctuations in tempera-

ture. By substituting the *actual* temperatures experienced upon each day of any given year, in place of the *mean daily* temperatures for a long series of years, the irregularities of the annual curve become enormously increased. The extent to which the temperatures experienced upon a given day of the year have varied in past years is shown in curves A, C, and D in Plate IV. For example, on the 11th day of February, 1899, the minimum temperature at Baltimore was 6° below zero; on the 11th of February in 1887, the maximum was 72° above zero, an extreme range of 78° for the 11th of February. Even in the summer months, when the variability in temperature conditions is least marked, the extreme ranges are about 40°.

While differences in temperature constitute the most conspicuous feature of the weather of successive seasons in most portions of the middle latitudes, the character and amount of precipitation, and the duration and the force of the wind are factors of great importance, and indeed these sometimes overshadow the temperature changes.

The departures from the normal conditions of temperature, precipitation and wind experienced in a given season, must be referred back to the prevailing type of pressure distribution upon which they depend. A clear knowledge of the relative distribution of pressure over a widely extended area is essential to a proper understanding of the weather changes in any given locality; this knowledge should extend, not only to the rapidly moving cyclones and anti-cyclones, but also to the larger areas of high and low pressure known as permanent cyclones and anti-cyclones, which are a direct result of the general atmospheric circulation.[1]

As a result of the increasing cold of the winter months there is formed over the North American continent a vast anti-cyclonic area. With the passing of the winter, this gradually disappears to give place to a barometric depression, or cyclone. The process is reversed over the neighboring oceans; here, while the contrasts between the winter and summer pressure distribution are not so marked, the pressure is lower in winter

[1] *See:* Teisserence de Bort; Étude sur l'hiver de 1879-80. Ann. du Bureau Centr. Met'l., Paris, Vol. IV, 1881.

than in summer. The changes in the intensity and in the position of these great atmospheric systems have a direct influence upon the character of the seasons over the eastern portions of the United States, and especially in the Atlantic coast states.[2] The best developed and most conspicuous instance of this semi-annual transfer of vast quantities of air from the continent to ocean during the winter and from ocean to continent during the summer, is seen in the winter and summer monsoons over India and the Indian Ocean.

Bearing in mind what has been said concerning the influence of pressure distribution on the direction of winds, and hence on temperature and precipitation, we may realize how variations from the normal type of pressure distribution for a given month or season will affect the general character of the weather of the period in question. This influence may be graphically shown by calculating the mean monthly distribution of atmospheric pressure over the North American Continent and adjacent oceans during an abnormally cold month and an abnormally warm month, and charting the results in connection with a map showing the normal distribution of pressure based on a long series of years of observation. This has been done in succeeding pages for the months of January, April, June, and October as types for the winter, spring, summer, and autumn seasons respectively.

In the succeeding pages some of the more conspicuous types of cyclonic and anti-cyclonic control of the weather of the Middle Atlantic states will be considered in connection with a discussion of the seasons in which they most frequently occur.

WINTER WEATHER.

The winter season presents the most variable weather conditions of the year. Practically every type of weather may be experienced at one time or another during the course of the three months, and sometimes a great variety of types may be crowded into the short period of 24 to 48

[2] *See:* O. L. Fassig. Types of March Weather in the United States. Amer. Journ. Sci., New Haven, November, 1899, Vol. III.

hours. A description of winter weather conditions which prevail in the vicinity of Baltimore would include all the types of the year, though some of them attain their greatest development in other seasons.

An account of weather conditions from day to day in our latitudes is mostly confined to a consideration of the eastwardly moving procession of cyclonic and anti-cyclonic systems across the United States. While for purposes of convenience and clearness our descriptions are confined to well developed types, the fact must not be overlooked that the faintly developed systems are the most frequent and consequently in the long run determine the general character of the weather of a given locality.

All of our weather types may be roughly separated into two fairly distinct classes—(a) areas of unsettled weather accompanying the passage of cyclones, or areas of low pressure—(b) areas of fair weather associated with passing anti-cyclones, or areas of high pressure. While it is often difficult to distinguish these types clearly it will be found of great convenience to adhere to the classification in the following pages.

Winter Cyclones.

As stated in preceding paragraphs, the weather of our middle latitudes is characterized by an irregular succession of atmospheric waves passing from west to east; the areas in which the barometer reads high corresponding with the crest of the waves, while the areas of low barometric pressure may be compared with the troughs. When these crests and troughs are well developed and sharply defined the latter are known as cyclones, or simply as storms, while the crests are called anti-cyclones; in the winter season when these anti-cyclones develop to unusual intensity they constitute our cold waves. When they are well developed and move with average speed across the country these cylonic disturbances usually cover a period of two to three days in passing a given meridian. As they pass over a region they bring to it a fairly regular sequence of weather changes. The character of these successive changes is modified by various conditions. First in importance is the position of the region with reference to the center of the barometric depression, or storm. The path traversed by the center of the storm with reference to Baltimore depends largely upon the place of its origin.

In selecting a series of storms for illustration to show the different varieties of weather experienced in the vicinity of Baltimore during the course of the year, it will be found convenient to classify them, basing the classification upon the place of origin of the depression, or, perhaps better, the position of the center of the depression a day or two before its arrival over the region about Baltimore.

Four types will be described in the order of their percentage of frequency across the horizon of Baltimore—the Lake storm, the Southwest storm, the Gulf storm, and the Coast storm. These types imperceptibly merge into one another at times, but they have sufficient individuality to permit of ready separation into the classes named.

All of these classes show their most intense development in the winter season, with perhaps the exception of the Coast storm; the latter is likely to be the northward extension of a West Indian hurricane, and hence shows a maximum frequency in the early autumn, or late summer.

THE LAKE STORM.

The Storm of December 24-26, 1902.

The daily weather map of the United States Weather Bureau for 8 a. m., December 23, 1902, shows a distribution of pressure which caused a fairly normal condition of winter temperatures. A barometric pressure above the seasonal average prevailed over the eastern half of the country with a maximum over the Great Lakes, giving rise to northerly winds east of the Mississippi River. A depression, first shown on the map of the 22d over Puget Sound, had made its way eastward to Montana and North Dakota. West of the Mississippi this depression had already shown its influence in a drift of southerly winds towards the center of depression, but the isotherms had not as yet been greatly bent from their normal trend. Twenty-four hours later, at 8 a. m. of the 24th, the center of the depression had moved eastward a distance of about 600 miles, its center being over Lake Superior. The effect of 24 hours of southerly winds in advance of the center of the storm, coupled with the southward flow of winds from the colder northwest quadrant behind the storm center, changed the isotherms from their normal east-west

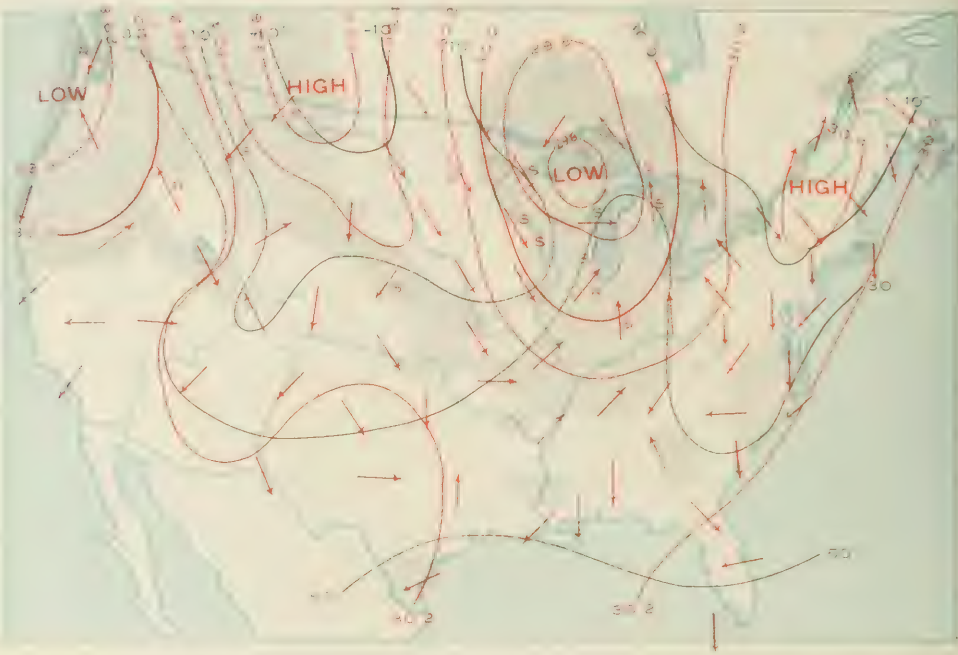


FIG. 91.—The Lake Storm of December 24, 1902.

FIG 92.—The Lake Storm of December 25, 1902.

trend to north-south lines. Temperatures in advance of the center were raised 15° to 20° in the southeast quadrant, while there was a fall of equal amount in the southwest quadrant. On its way eastward the area of precipitation grew in extent. The temperatures on all sides of the storm center being below freezing point the precipitation was practically all in the form of snow. As is most frequently the case, the storm area was oval in shape, with its long axis extending north and south;

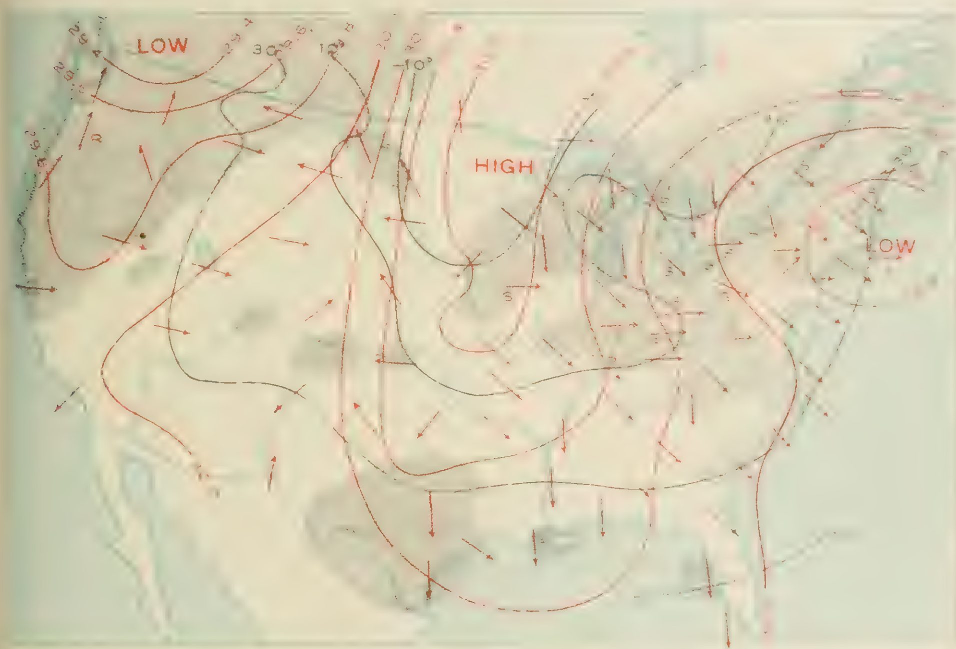


FIG. 93.—The Lake Storm of December 26, 1902.

as a result the winds about the center blew from the southeast in advance of the long axis, and from the northwest in the rear of the advancing central line, on both sides blowing towards the trough of the lowest pressure.

By Christmas morning the storm center had moved eastward to the Lower Lake region, a distance of about 500 miles, and before the close of the day the trough of lowest pressure had crossed the meridian of Baltimore. The eastern edge of the area of snowfall had reached the

Atlantic coast by 8 a. m., from Massachusetts to North Carolina. During the preceding 12 hours snow had fallen in varying amounts over the entire area from Chicago eastward to the Atlantic coast, and from the Lakes southward to North Carolina. The area in advance of the storm over which the temperatures rose 15° to 20° now extended to the coast, while a cold wave (an area of high pressure) followed close behind the storm center, attended by northwesterly winds and clear skies.

By 8 a. m. of the 26th of December, the center of the storm had reached the New England coast in its due eastward progress, covering another 600 miles in the preceding 24 hours. Here it remained nearly stationary for 24 hours before continuing its eastward course over the North Atlantic Ocean. By this time the area of high barometric pressure following the storm had spread over the entire region from the Rocky Mountains eastward to the Atlantic coast and from the Lakes to the Gulf coast, carrying freezing temperatures southward into Middle Florida.

The weather map of December 27th shows a condition which frequently occurs in the winter months—a striking inversion of temperatures between Florida and Nova Scotia. Jacksonville, Fla., had a temperature of 24° at 8 a. m., while Sydney, N. S., reported a temperature of 40° at the same hour. The reason for this apparent anomaly is readily found on examining the weather maps of the preceding days. The cold northwest winds flowing out of the area of high pressure in the rear of the advancing storm had reached the Gulf states while the warm southerly winds were still blowing over Nova Scotia in the southeast quadrant of the storm area.

The path of this storm of December 24-26, 1902, from the Lake region eastward is the approximate path of nearly three-fourths of the barometric depressions which exert a direct influence upon the weather conditions in the vicinity of Baltimore. The path of the center lies well to the north of Baltimore. The successive changes in the elements of the weather experienced during the passage of this type of storm across the meridian of Baltimore are graphically illustrated in the accompanying diagram, a brief description of which will suffice to call attention to the most important factors. (See Figs. 91-94.)

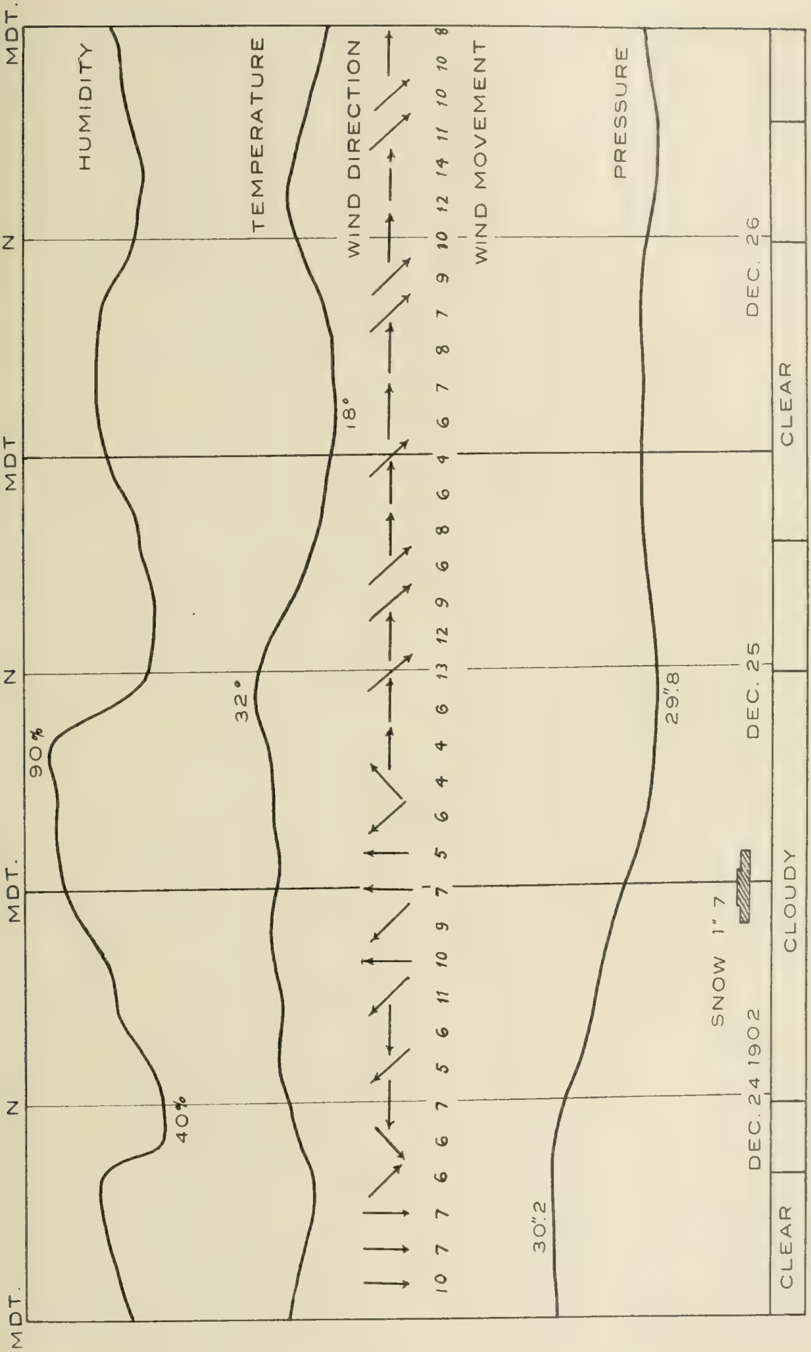


FIG. 94.—The Lake Storm of December 24-26, 1902.

Within the horizon of Baltimore the approach of the storm from the west was announced by a steady fall in the height of the mercury in the barometer after 10 o'clock in the morning of the 24th of December. The day began with clear skies; soon after sunrise the clouds began to form, increasing in amount until the sky became overcast by 10 a. m. The winds blew from the north in the early morning. About 10 a. m. the direction changed to northeast, continuing to veer to east and then to southeast and south with the continued fall of the barometer. Coincident with the changes in the wind from north to east and southeast the temperature rose steadily until nearly midnight; the usual diurnal fall in temperature after 3 p. m. being eliminated by the cyclonic rise. The barometer continued to fall until 8 a. m. of Christmas day, the time at which the trough of lowest pressure of the storm area crossed the meridian of Baltimore. At about the same hour the wind veered from southeast to southwest. The temperature continued to rise until 10 a. m. and then fell steadily with the persistent blowing of west to northwest winds. The humidity increased from 40 per cent at 10 a. m. of the 24th, when the winds changed to an easterly direction, to a maximum of 90 per cent at 8 a. m. of the 28th. With the change of wind from southerly to westerly the humidity fell rapidly to 45 per cent within a period of about two hours.

A light dry snow began to fall between 10 and 11 p. m. of the 24th, with a falling barometer and a southerly wind. The snow continued until 2 a. m. of the 25th, the total amount being about three inches. The sky remained overcast until 10 a. m. of the 25th, when the clouds began to break away soon after the shift of the wind from southeast to southwest. By 8 p. m. the sky was clear. The usual sharp rise in pressure after the storm was not experienced in the passage of this depression, the barometer remaining comparatively low through the 25th and 26th. As a result there were no high winds in Baltimore during the progress of the storm; there was a slight increase in velocity, however, following the turn in the barometer and the change in direction of the wind from west to northwest.

The series of maps showing the progress of this storm across the United States well illustrates the normal winter conditions of a succes-

sion of areas of high and low pressure moving from west to east across the continent. On the map of December 24th we see an area of high pressure over New England, a depression over the Upper Lake region, another high area over Montana and the Canadian Northwest, and another depression appearing on the Pacific coast over Oregon and Washington. These systems move eastward at an average rate of about 600 miles per day with their centers mostly between the 40th and 50th parallels of latitude, bringing to localities over which they pass their characteristic changes in temperature, in wind direction and force, in clouds and sunshine, and in rainfall or snowfall.

The Storm of January 7-8, 1903.

The daily charts of January 6, 7, and 8, 1903, issued by the United States Weather Bureau, show the progress of another storm of the Lake region type. On the 5th a depression appeared upon the field of the map in the extreme northwest of the Canadian Provinces. By 8 a. m. of the 6th the depression had crossed the boundary line into North Dakota as a well developed storm, its influence being felt over most of the area between the Rocky Mountains and the Mississippi Valley.

In the succeeding 24 hours the center of the storm had traversed a distance of nearly a thousand miles, from Quapelle, Manitoba, to Central Michigan. The depression developed no precipitation area until the night of the 6th. By 8 a. m. of the 7th snow had fallen over a symmetrical oval area about the center, extending about a thousand miles from east to west and about six hundred miles from north to south. Passing eastward with the same rapid rate of progress the center moved over Nova Scotia by 8 a. m. of the following day. While the area of snowfall attending this storm reached as far south as Tennessee and North Carolina, the precipitation was extremely light in Maryland and Virginia, and was of short duration. The rainfall or snowfall in Baltimore and vicinity is generally light and falls in the form of brief showers or snow flurries with storms of this type, unless their centers pass the meridian of Baltimore within a hundred miles, or less, to the north, when the precipitation may be heavy and of considerable duration.

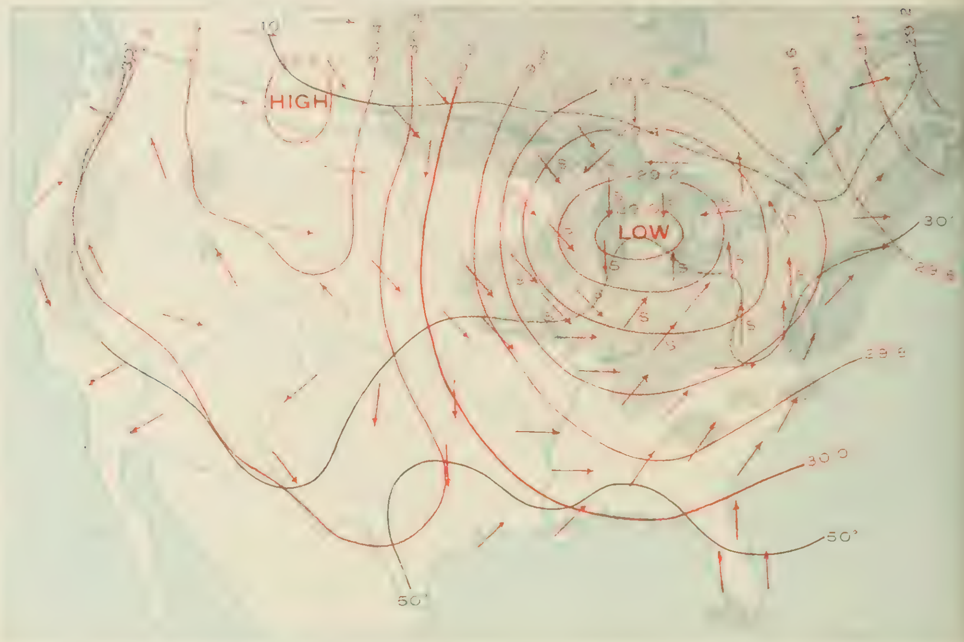


FIG. 95.—The Lake Storm of January 7, 1903.

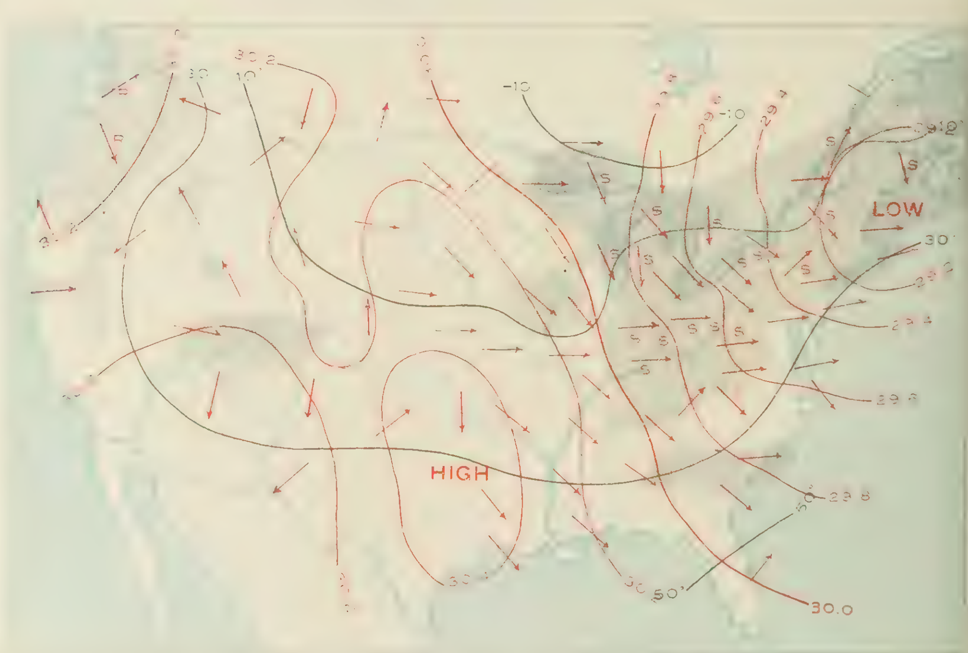


FIG. 96.—The Lake Storm of January 8, 1903.

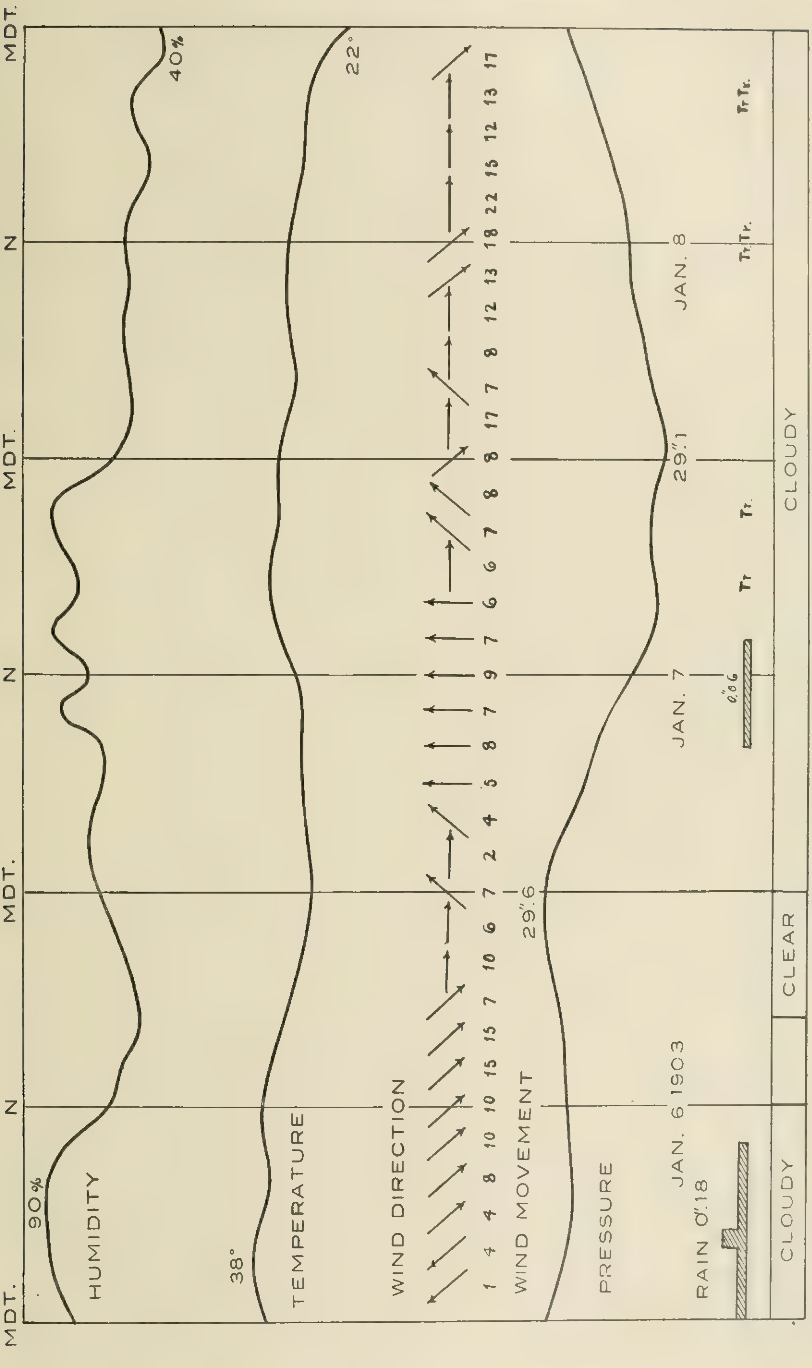


FIG. 97.—The Lake Storm of January 6-8, 1903.

In this storm the normal trend of the isotherms was not disturbed to the same extent as in the case of the storm of December 24-26, 1902, described above. The usual decided fall in temperature (20 degrees or more) followed in the path of the storm, but in this instance the cold wave was nearly 24 hours behind the center of the depression and did not reach the Atlantic coast. The local changes during the progress of the storm were not very pronounced but they were representative of the type following a similar path. Early in the morning of the 7th Baltimore came within the area of influence of the Lake storm described above. The barometer began to fall about midnight of the 6th-7th, the wind changed at the same time from northwest to west and soon after to the southwest; by 6 a. m. the wind had backed to the south and this direction prevailed until 4 p. m. Between 4 and 5 p. m. there was an abrupt change of the wind from south to west, accompanied by a rise in the barometer. The pressure rose slowly though steadily throughout January 8th as the center of the depression moved over the Atlantic off the New England coast. The wind did not materially increase in force until 2 a. m., about 10 hours after the beginning of the rise in the barometer, attaining a maximum velocity of 28 miles per hour before noon.

The passage of a coast storm on the 5th-6th left a raw blustery wind blowing from the west and northwest in the afternoon of the 6th, with clearing skies. Cloudiness increased during the morning of the 7th upon the approach of the Lake depression and the sky soon became overcast. There was a brief breaking away of the clouds between three and four p. m. Light snow fell between 8.30 and 10.30 a. m. of the 7th, between 11.50 a. m. and 1.45 p. m., between 4 p. m. and 5.30 p. m., and again between 9.15 and 9.40 p. m. The total fall of snow was not much over half an inch. During the 8th the sky was overcast with only occasional brief intervals of sunshine. There was a slow and steady fall in temperature and a steady rise in the barometer, with brisk westerly winds in the forenoon. Traces of snow fell between 11.20 and 11.51 a. m., 12.05 and 12.25 p. m., and between 7.55 and 8.25 p. m.

The rise in temperature in advance of the storm was not well marked.

This may be readily accounted for by the brief duration of the southerly winds in advance of the center, covering a period of less than 10 hours. (See Figs. 95-97.)

The Storm of February 27-March 1, 1903.

These Lake storms sometimes develop into disturbances of great extent and intensity. The weather chart of 8 a. m., February 27, shows a depression centered over Eastern Nebraska, formed apparently by the union of two distinct depressions; one of these had its origin in the Canadian Northwest Provinces, the other in the extreme southwest, over Arizona. By 8 a. m. of the 27th a very considerable rain area had already developed over the Central and Southern states, aided largely by the presence of a well developed area of high barometric pressure over the Atlantic Ocean off the Middle Atlantic states. During the succeeding 24 hours the storm area grew to unusual proportions, while it moved eastward across the Lake region at a rate slightly above the normal rate of progress for such storms. By 8 a. m. of the 28th the precipitation area of the preceding 12 hours embraced all of the country east of the Mississippi River. To the south and east of the storm center the areas in which southerly winds prevailed, temperatures rose from 15° to 40°, and the precipitation was in the form of rain; west of the center of the storm, in the area of northwest winds, there was a fall of 20° to 30° in 24 hours. The rain area was not only of unusual extent, but the eastward movement of the storm was marked by very heavy rains, measuring an inch and a half to two and a half inches in 24 hours at many stations in the South Atlantic and Gulf states. The passage of the trough of low pressure was also the occasion for the production of severe squalls and local storms. By the morning of March 1 the storm center had moved eastward to the Gulf of St. Lawrence followed closely by a fall of 20° to 30° over a large area, embracing a dozen or more states.

The local changes during the passage of this wide-spread storm across the meridian of Baltimore were exceptionally well marked and characteristic of the well developed storm of the type with a path across the Lake region and down the St. Lawrence Valley. (See Figs. 98-101.)

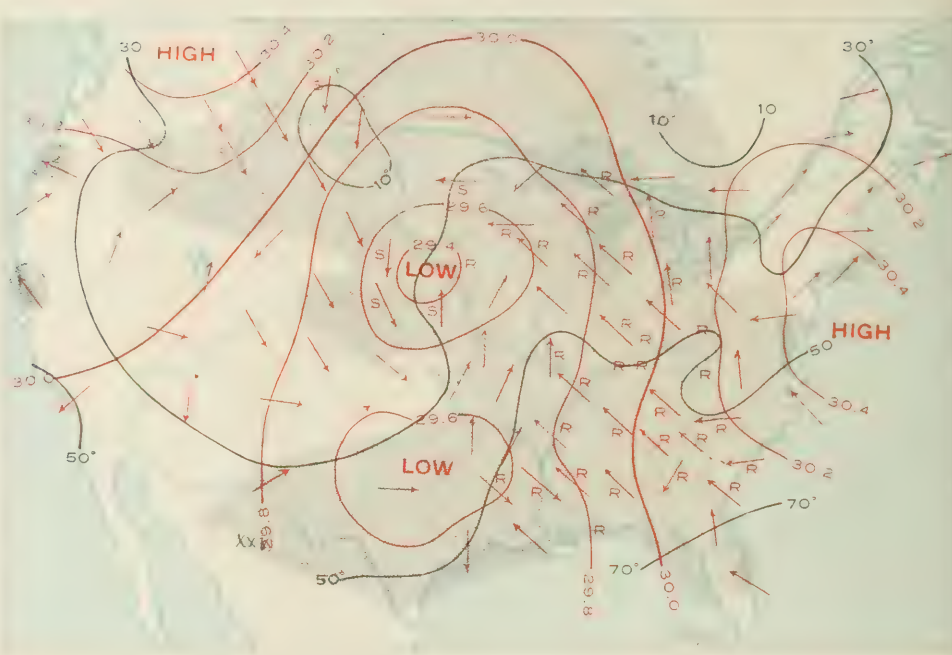


FIG. 98.—The Lake Storm of February 27, 1903.

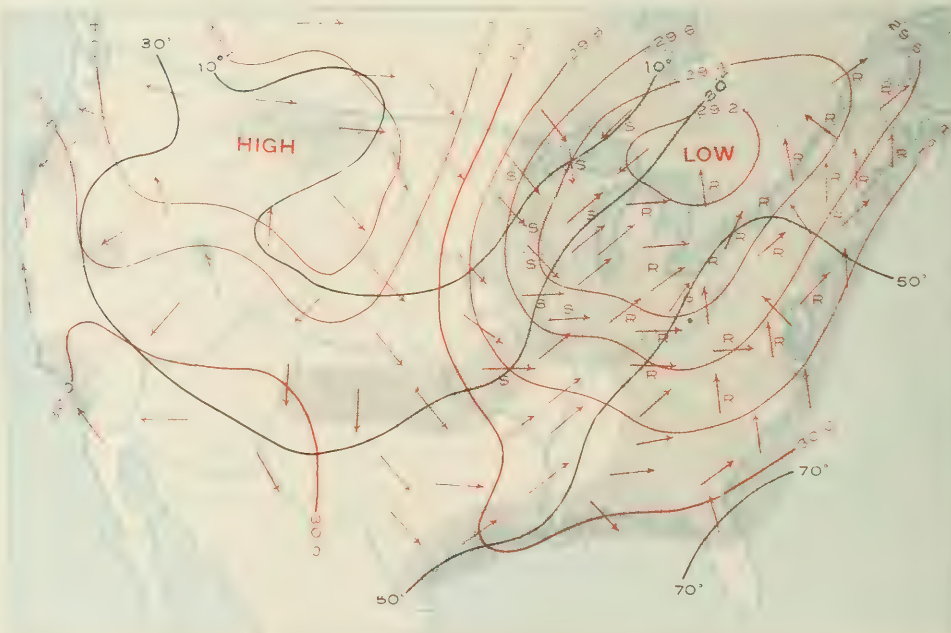


FIG. 99.—The Lake Storm of February 28, 1903.

On the morning of the 26th an area of high barometric pressure rested over the Atlantic states, with its center over Maryland and Virginia. The winds were light and variable in direction. The skies were clear, resulting in heavy frosts during the preceding night and in the early morning hours, throughout the state.

With clear skies and light winds the temperature rose rapidly during the day, and the air became balmy and spring-like. There were a few

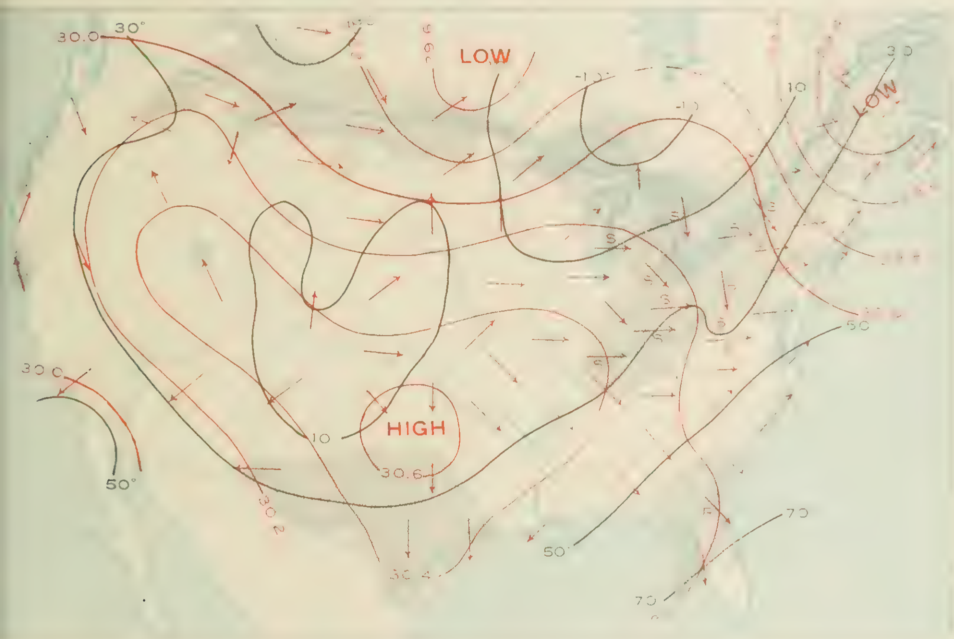


FIG. 100.—The Lake Storm of March 1, 1903.

cirro-stratus clouds in the early morning, but they soon disappeared. At 10.40 a. m. the local Weather Bureau Office received the following telegram from the Central Office in Washington: "Southeast storm warnings ordered hoisted along the Atlantic coast from Miami, Fla., to Charleston, S. C. Storm over Texas is moving northeastward. Brisk to high easterly winds are indicated this evening and tonight on the South Atlantic coast."

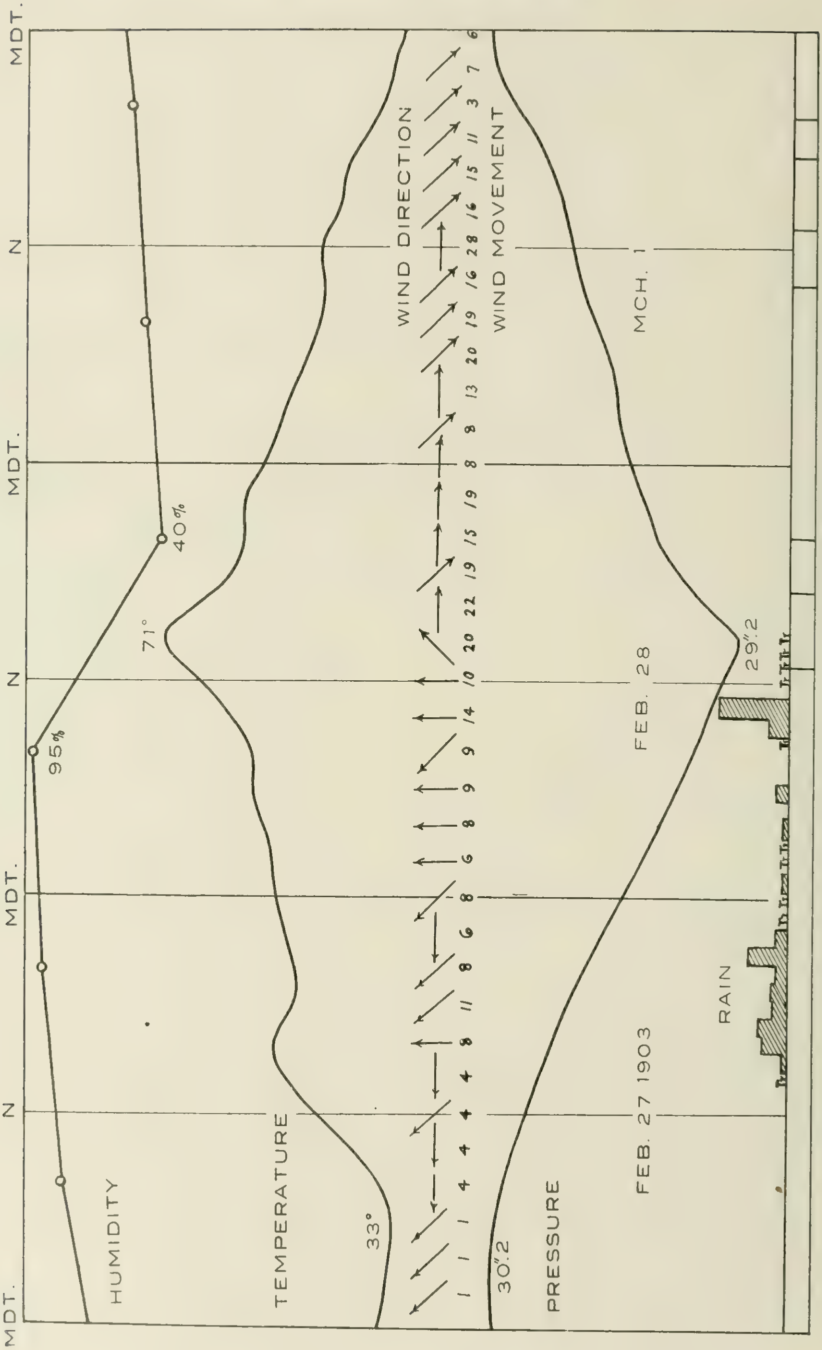


Fig. 101.—The Lake Storm of February 27-March 1, 1903.

Clouds gathered during the night, and at dawn of the 27th the sky was entirely overcast with a thin veil of stratus clouds. The atmosphere was humid and the clouds began to thicken. A solar corona was observed in the forenoon. The barometer fell steadily and rapidly throughout the day, the wind changed to southeast and east, while the temperature rose rapidly from a minimum of 33° at 6 a. m. to 52° at 4 p. m. A light rain fell from 2 p. m. to 2.10 p. m., began again at 3.35 p. m., continuing through the night. The amount of rainfall at midnight was 0.68 inch. At 11.45 a. m. southeast storm warnings were ordered up along the Atlantic coast as far north as Ft. Monroe, and later, southwest storm warnings were ordered from Baltimore to New York.

The following day, February 28, was cloudy and warmer. The atmosphere was humid and oppressive in the forenoon, but became more pleasant in the afternoon. Light fog formed during the night; at dawn it was dense, but soon became lighter, disappearing by 11 a. m. About 1 p. m. there was a temporary break in the clouds, but in about an hour a heavy stratus mass arose and rapidly covered the sky. At 10.30 a. m. storm warnings were ordered changed to northwest from South Carolina to Virginia. The rain which began on the preceding day continued to 7 a. m., began again about 8.30 a. m.; it was heavy for a few minutes after 10 a. m. and continued with brief interruptions until 3.15 p. m. The total fall from midnight was 0.46 inch. The winds were fresh to brisk between 10 and 11 a. m., increasing in the afternoon and evening to high; the maximum velocity was 38 miles from the west at 2.45 p. m.

The barometer continued to fall rapidly to a minimum of 29.27 inches at 2 p. m., while the temperature rose steadily from 52° at midnight to 71° at 2 p. m. At this hour the wind veered from south to southwest and then to the west, accompanied by a rapid rise in the barometer and a sharp fall in the temperature. The atmosphere became crisp and invigorating throughout the balance of the day, and the day following (March 1) the barometer rose and the temperature fell rapidly and steadily, while the wind continued from the west and northwest.

During the passage of this storm the temperature rose 38° in advance of the center, from a minimum of 33° at 6 a. m. of February 27 to a

maximum of 71° at 2 p. m. of the 28th. The barometer fell an inch during the same period. After the passing of the center of the storm across the meridian of Baltimore the temperature fell 38° in 30 hours, while the barometer rose over an inch during the same period.

THE SOUTHWEST STORM.

A much frequented path for storms has its origin in the Southwest and trends northeastward across the Lake region and down the St. Lawrence Valley, or across the New England states. Storms of this type may have their origin in the extreme northwest, or they may enter the United States from the Pacific Ocean off the coast of California, but they dip far to the south, their centers passing over Oklahoma or Texas, before proceeding on their way eastward by way of the Lake region. In their journey southeastward these storms gather energy and moisture with increase in temperature. They are characterized by a sharp rise in temperature in advance of the center of the depression, as the warm moisture laden southerly winds from the Gulf and South Atlantic are drawn into the circulation for a relatively long period. As they move northward the temperature is not only lowered by rising currents in advance of the storm, but also by reason of their entrance into cooler latitudes. As a result of the lowering of temperature and their proximity to the main sources of water supply—the Gulf and the Atlantic Ocean—clouds and rain form rapidly over a very large area about their centers. While the paths of such storms may not pass in closer proximity to Baltimore than do the Northwest Lake storms, their rain areas extend farther southward and eastward from their centers and hence bring to Baltimore a longer period of unsettled weather and a heavier rainfall.

The Storm of February 3-5, 1903.

This storm entered the United States from the Pacific Ocean on February 1. At 8 a. m. of the 2d its center was over Arizona, and on the 3d over Texas. During the succeeding 24 hours the storm turned sharply to the northeast, increasing in energy and area, reaching Lake Michigan by 8 a. m. of the 4th. By this time the rain area had already

reached the Atlantic coast from Florida to Maine, while it extended westward to Nebraska.

In its southeast quadrant the temperature rose 20° or more in 24 hours, while a marked cold wave closely followed the center of the depression to the southwest, with a fall of 20° to 40° in 24 hours. In advance of the storm the precipitation occurred as rain, excepting in the northeast where the temperature fell below 32°. Here, and to the west of the

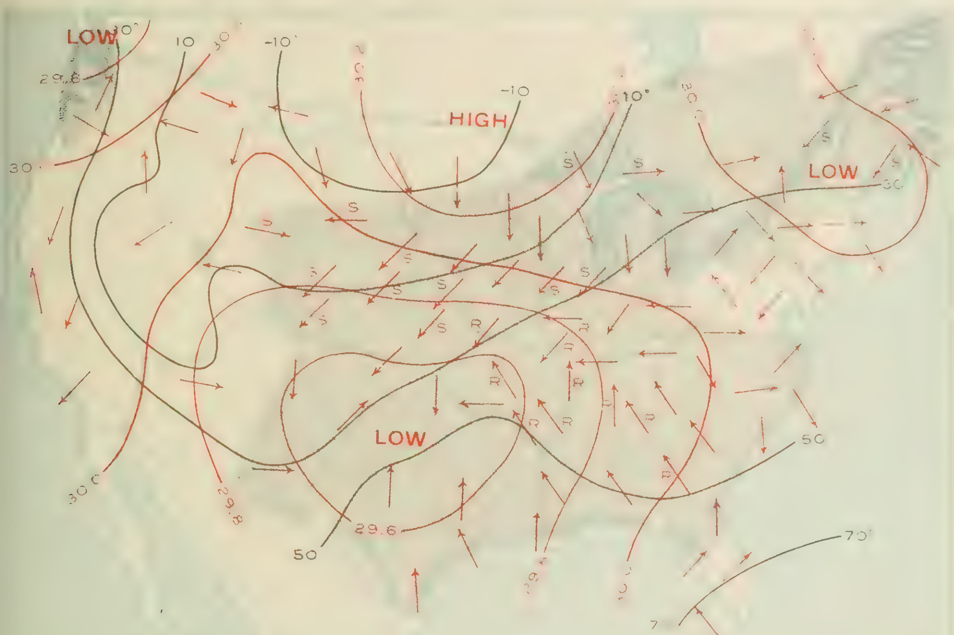


FIG. 102.—The Southwest Storm of February 3, 1903.

storm center, snow fell over a large area, in many places to a great depth. The barometric gradients in this storm were very steep, the difference between the pressure at the center and the outer edge of the storm being an inch or more. (See Figs. 102-105.)

The following description of the conditions at Baltimore during the passage of this storm is taken from the records of the local office of the United States Weather Bureau:

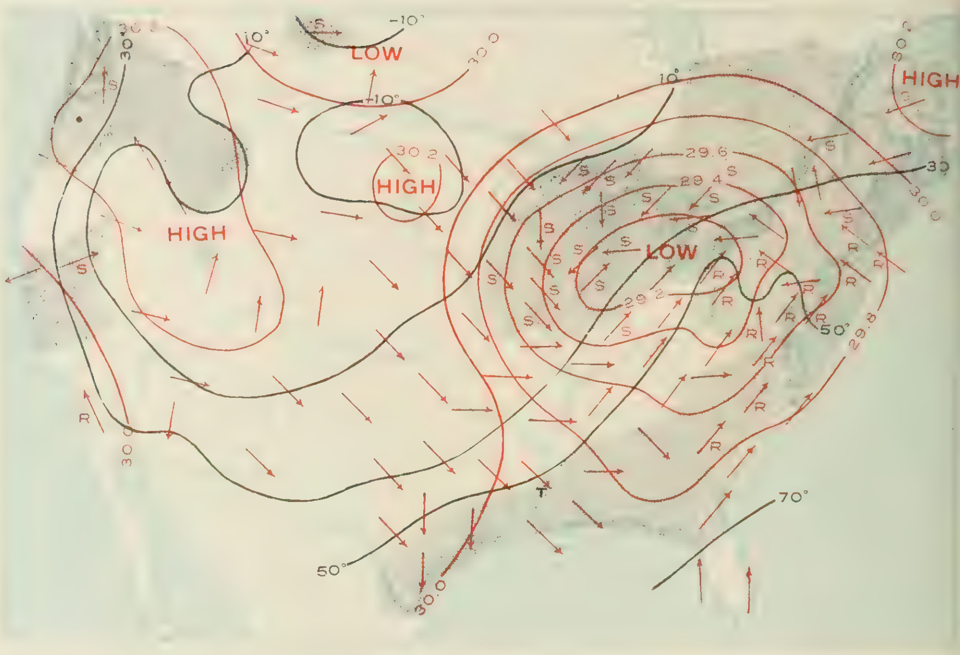


FIG. 103.—The Southwest Storm of February 4, 1903.

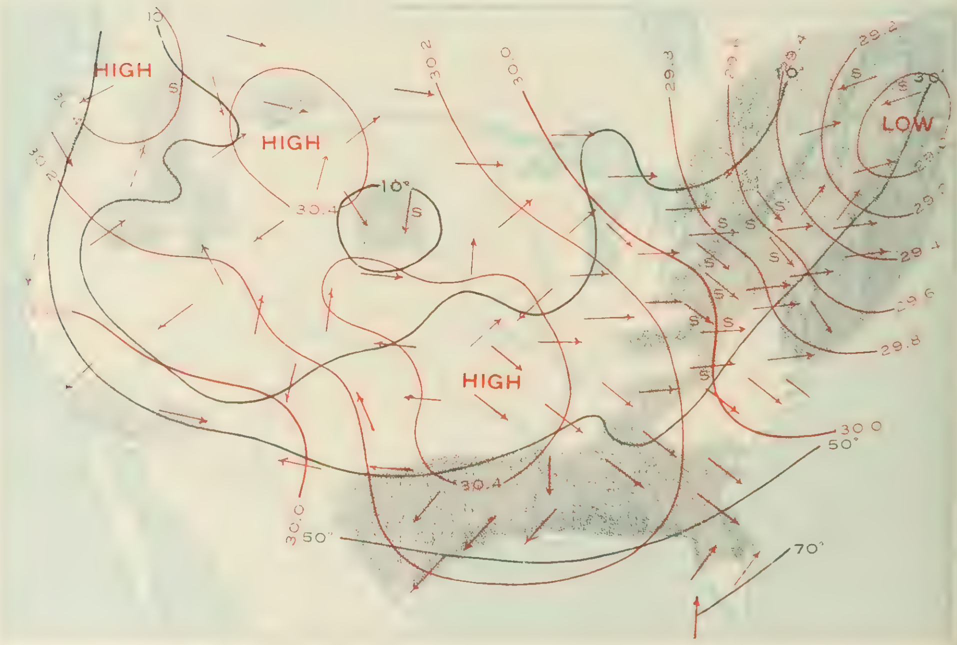


FIG. 104.—The Southwest Storm of February 5, 1903.

February 3, 1903. A warm cloudy day. Cirrus clouds formed rapidly after 7 a. m., the sky becoming overcast by 10 a. m. The clouds increased in density. Light rain began at 10.55 p. m. and continued into the night. At midnight the amount of precipitation was 0.05 inch. The atmosphere was balmy and springlike.

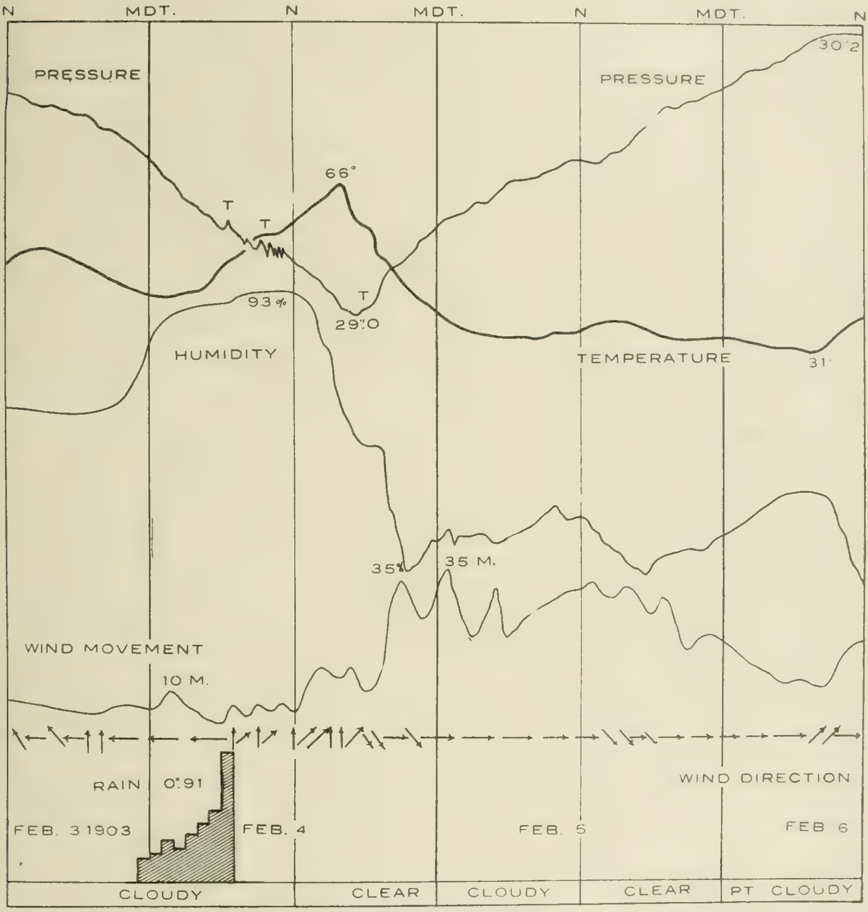


FIG. 105.—The Southwest Storm of February 3-6, 1903.

February 4, 1903. The day continued cloudy and warm with a sultry atmosphere in the morning. The temperature rose to 66° at 4 p. m., then fell sharply 7° just before 5 p. m., followed by a steady fall. The sky was overcast until 1.50 p. m. The strato-cumulus clouds changed to cumulus by 2.30 p. m.; these in turn disappearing by 4 p. m. Dense fog prevailed during the

preceding night, became light in the early morning, and disappeared by 10.30 a. m. The light rain of the night before continued into the morning, becoming heavy about 6.30 a. m., 0.20 inch falling in 5 minutes. This brief downpour was preceded by a single flash of lightning. The rain continued at intervals until 8.30 a. m. The total fall from midnight was 0.86 inch. A slight peal of thunder was heard at 10.21 a. m. At 4.50 p. m. there appeared an inky-black, closely compacted mass of strato-cumulus clouds, driven from the northwest, though the cloud mass showed a distinct northeastward movement. By 5 p. m. the entire mass had risen above the western horizon, covering about six-tenths of the sky. On the northern edge of the cloud mass several cumulo-nimbus of the "anvil" variety were seen. Rising above the western horizon were cumuli, small in size, and extending north and south for about 25°, with an overlying cirro-stratus layer. There were three air currents: The upper current was moving from the west; the middle current from the southwest; the surface wind was from the northwest. Though the cloud mass moved eastward in a body, the northeast end seemed fixed, and a general commotion was noticed in the base of the cloud strata in this portion; mammo-cumulus clouds appeared and disappeared for about ten minutes. At 5.15 p. m. breaks occurred in the mass, exposing snow-white cumulus peaks with the crowns growing in size, indicating ascending air currents. At 5.30 p. m. the mass was steadily being pushed southeastward and an alto-stratus layer set in from the northwest. The western edge of the cloud mass passed over the station at 5.40 p. m. From this time until 6.50 p. m. the mass was very dark in color, except on the extreme northeast edge, where several snow-white mountainous cumulo-nimbus prevailed. From and among these cumulo-nimbus broad flashes of lightning were seen from 5.50 p. m. until 6.50 p. m. Two successive peals of thunder were faintly heard in the eastern suburbs of the city at 5.30 p. m. Southwest storm warnings were ordered up along the coast from Wilmington, N. C., to New York. The winds became brisk to high after 7 p. m., with a maximum velocity of 38 miles from the west at 7.15 p. m.

February 5, 1903. The day was partly cloudy and colder. The sky was overcast during the forenoon; clouds began to break away about noon, and by 3.30 p. m. they had disappeared. Brisk to high westerly winds continued throughout the night and during the day, decreasing to fresh in the evening; the maximum velocities exceeded 40 miles an hour. Considerable damage was done by the wind to signs and awnings, and a few houses were partially unroofed. Snow flurries occurred between 8 a. m. and 11 a. m., but no snow remained on the ground; the total fall was less than a tenth of an inch.

The Storm of December 26-28, 1904.

This disturbance, like the storm described in the preceding paragraphs, had its origin over the Pacific Ocean. Its center appeared off the coast of Oregon on the 24th inst. Moving rapidly southeastward across the

Rocky Mountains the storm reached Texas on the morning of the 26th; recurving sharply northeastward the center was over Central Illinois 24 hours later and over Toronto on the morning of the 28th. Following the usual course down the St. Lawrence Valley the storm passed eastward over Labrador to the Atlantic, crossing the continent from ocean to ocean in just five days along a path about 4000 miles in length. Assuming a uniform rate of speed the average daily movement was 800 miles. The rate varied from 1000 miles in 24 hours from the Pacific Ocean across the Rocky Mountains, to 500 miles in crossing the Lake region.

The storm was characterized by a precipitation area of unusual extent, and by heavy local rains and snows. The isotherms were bent from their normal east-west direction to a north-south trend near the center by the warm southerly winds in advance of, and the cold northwest winds in the rear of, the center of the storm. The rise in temperature in the southeast quadrant was 20° to 30°, while the subsequent fall in the southwest quadrant varied from 20° to 50° in 24 hours.

The local changes in Baltimore during the progress of this storm were well marked and characteristic. While the center of the storm was over Texas, on the morning of the 26th, an area of high barometric pressure rested over the New England states. This distribution of pressure caused north to northeast winds in the Middle Atlantic states. As the storm moved eastward and northward toward the Lake region the wind at Baltimore veered to east and southeast, and by noon of the 27th it had become south. During the night of the 27th-28th, while the center of the storm was over the Lake region, a secondary depression developed in the southeast quadrant of the main storm, over eastern Pennsylvania and New York, causing a sudden change of wind to north at Baltimore; as the storm center moved eastward the winds settled to northwest with rapidly increasing velocity.

The barometer fell from 30.24 inches at 8 a. m. of the 26th to 29.10 inches at 4 a. m. of the 28th, and rose again to 30.00 inches by 10 a. m. of the 29th. Co-incident with the fall in pressure and the changes in the direction of the wind to the south, noted above, the temperature rose from 26° at 6 a. m. of the 26th to 55° at 4 a. m. of the 28th, then

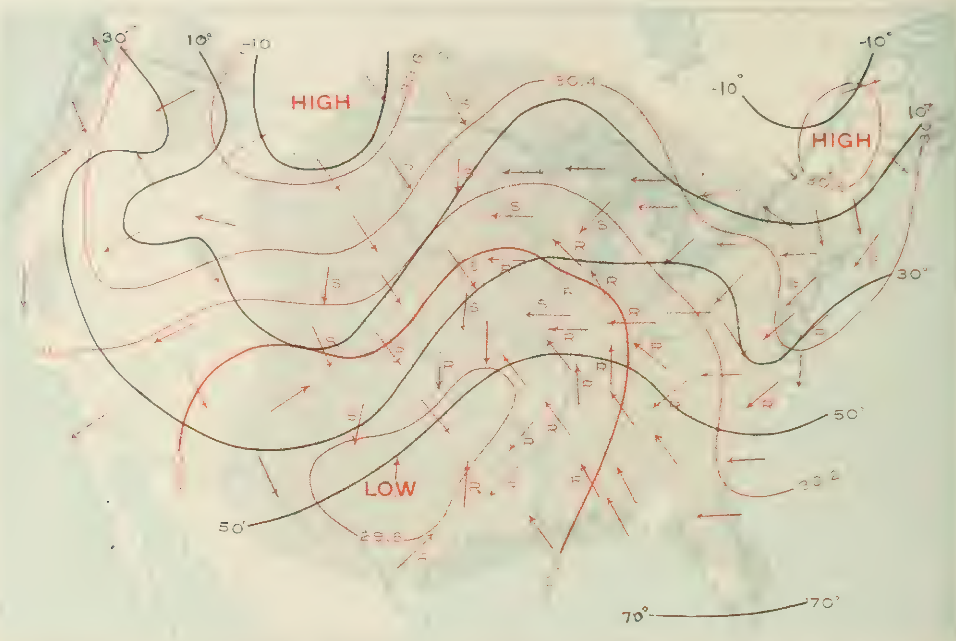


Fig. 106.—The Southwest Storm of December 26, 1904.

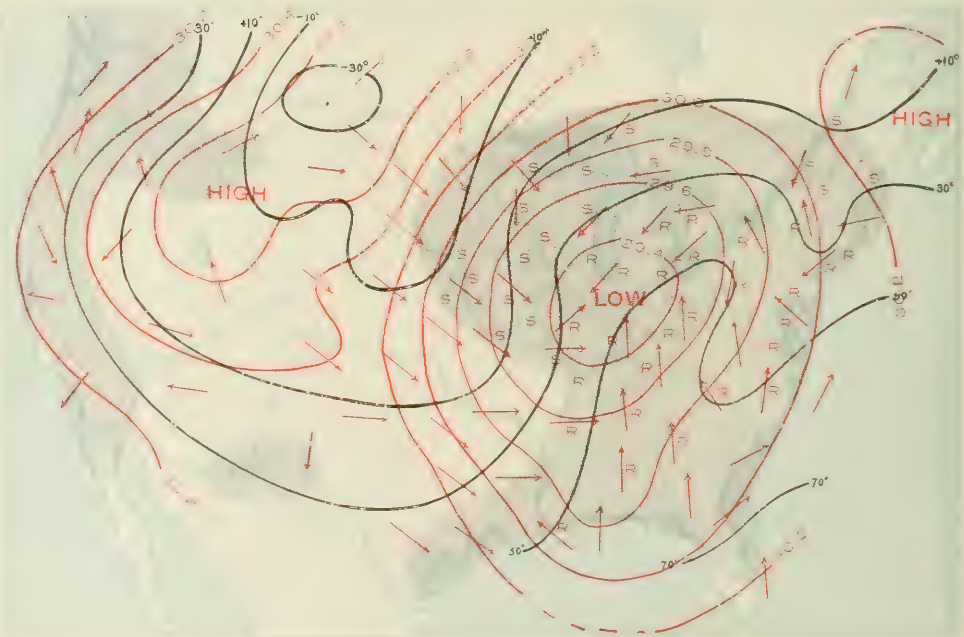


Fig. 107.—The Southwest Storm of December 27, 1904.

fell with change of wind to the north and northwest, to 20° at 6 a. m. of the 29th. This cyclonic rise and fall in temperature totally obliterated the diurnal fluctuation usually noted in the daily temperature curve. The maximum temperature occurred at 4 a. m. of the 28th. There was a steady rise during the 27th from midnight to midnight, and a steady and regular fall throughout the following day.

The rain was continuous but light. Beginning at 9 a. m. of the 26th as a light misting rain it continued as such without interruption until

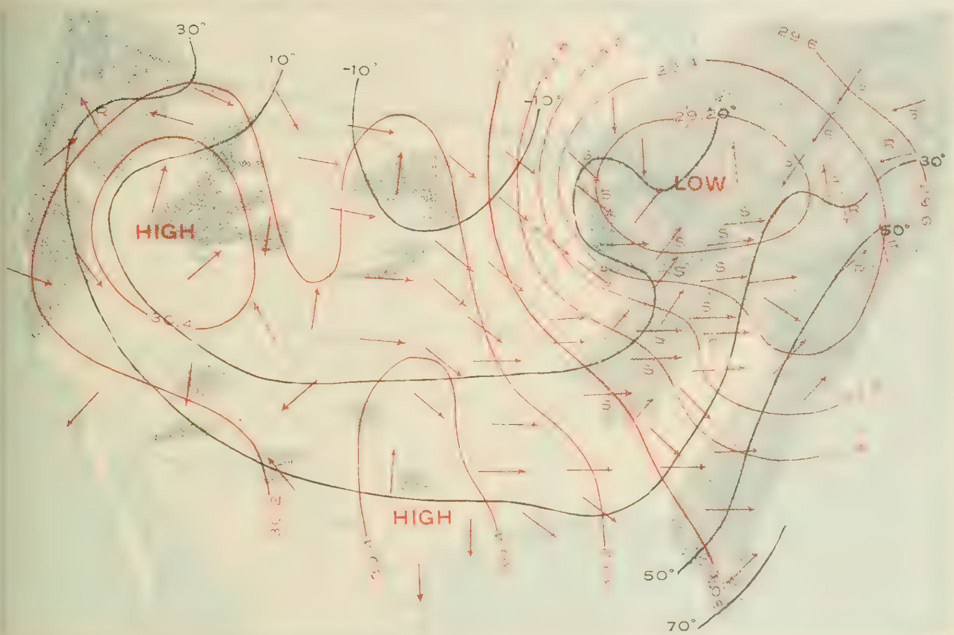


FIG. 108.—The Southwest Storm of December 28, 1904.

10.25 p. m., when it became heavier. About 6 a. m. of the 27th it again changed to a light mist which continued to the end of the precipitation period between 4 and 5 p. m. The total amount of rainfall (including some sleet) for the 32 hours was only 0.44 inch. (See Figs. 106-109.)

The daily journal of the local Weather Bureau Office contains the following remarks concerning conditions on the 27th and 28th:

December 27, 1904. A cloudy day. Continuous fog. Light rain, continuing from midnight yesterday, turned to misting rain at 6.05 a. m., and ended

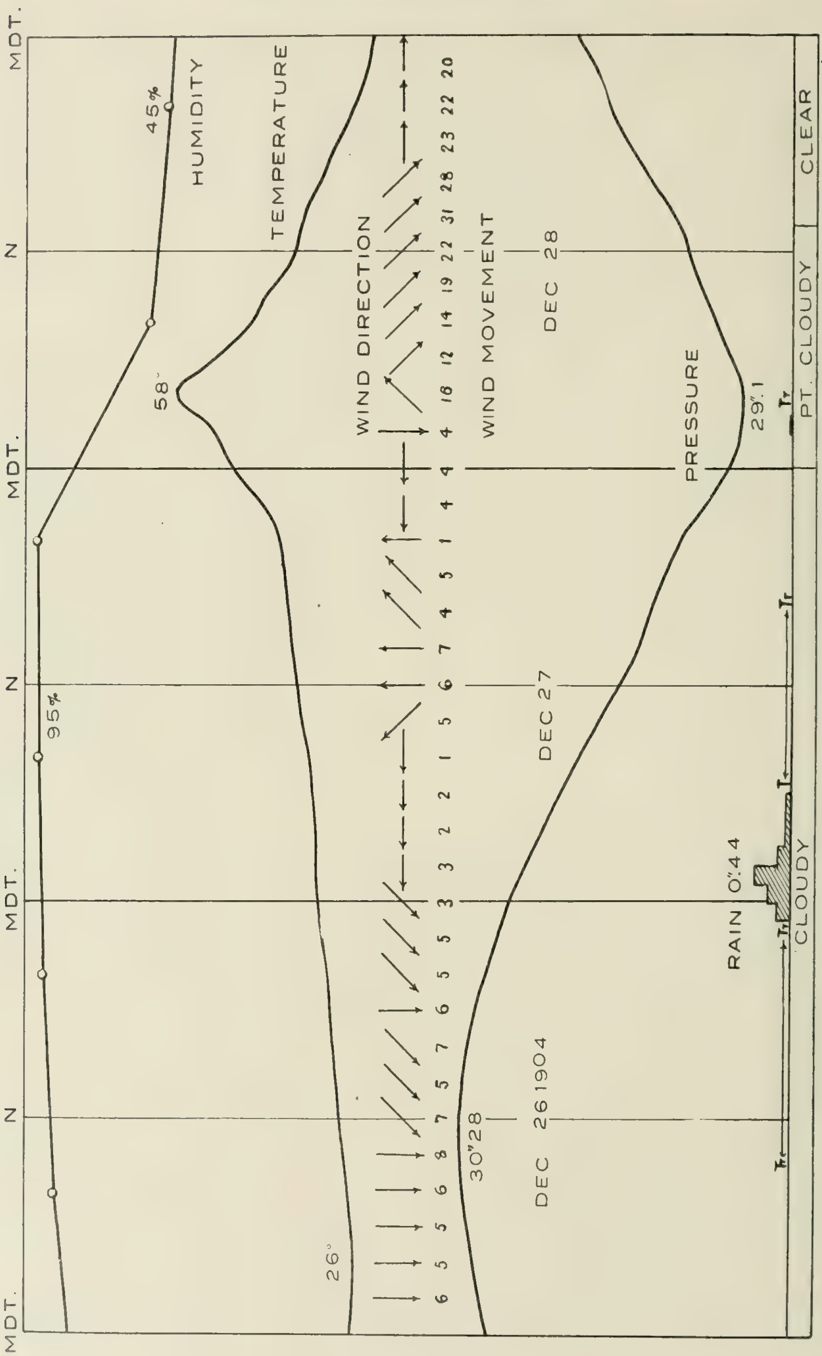


Fig. 109.—The Southwest Storm of December 26-28, 1904.

at 4.30 p. m. Southwest storm warnings were ordered up by the Chief of Bureau at 9.45 a. m. from Jacksonville, Fla., to Fort Monroe, and southeast warnings at 11.15 a. m. from Baltimore to New York. A cold wave warning was received at 9.55 p. m.

December 28, 1904. Partly cloudy until 9 a. m., followed by cloudy; clear after 1.30 p. m. A slow steady rise in temperature since Christmas morning culminated in a sharp rise to 55° at 4 a. m. From this hour the temperature fell steadily to 22° at midnight. Light rain fell between 1.15 a. m. and 2.10 a. m., amount 0.01 inch. The wind became brisk at 9.15 a. m. and continued so until nearly midnight. The velocity rose to a maximum of 40 miles per hour from the west at 12.45 p. m.

The Storm of December 12-13, 1903.

This storm first appeared within the field of view on the 10th of December in the extreme Northwest. It crossed the Rocky Mountain range in Montana in a southeast course during the night of the 10th-11th, and its center was over Missouri and Arkansas at 8 a. m. of the 12th. Here it recurved to the northeast, taking the usual course across the Lake region, down the St. Lawrence Valley and over Labrador, where it disappeared beyond the field of the weather map on the 14th inst. This storm resembled the southwest storm described above in most respects. There was an important difference, however, in the form of the system of isobars surrounding the center as the storm crossed the meridian of Baltimore on December 13. The oval shape of isobars, with the long axis extending approximately north and south is characteristic of many of this class of storms. The change from easterly to westerly winds, as the trough of low barometer moves eastward, is very abrupt, and is frequently attended by severe squalls or thunderstorms. The isotherms extend nearly north and south and are close together in the vicinity of the trough of low pressure, or, in other words, the temperature gradient is very steep and contrasts are great. In the case of this particular storm of the 13th there was a difference of 50° at 8 a. m. between Baltimore and Indianapolis, on the same parallel of latitude, or a difference of 50° between the southerly winds prevailing in advance of the center and the northwest winds which blew out of the well developed area of high pressure in the rear of the storm.

The trough of low pressure passed over Baltimore almost at the exact time of the 8 a. m. observations of the United States Weather

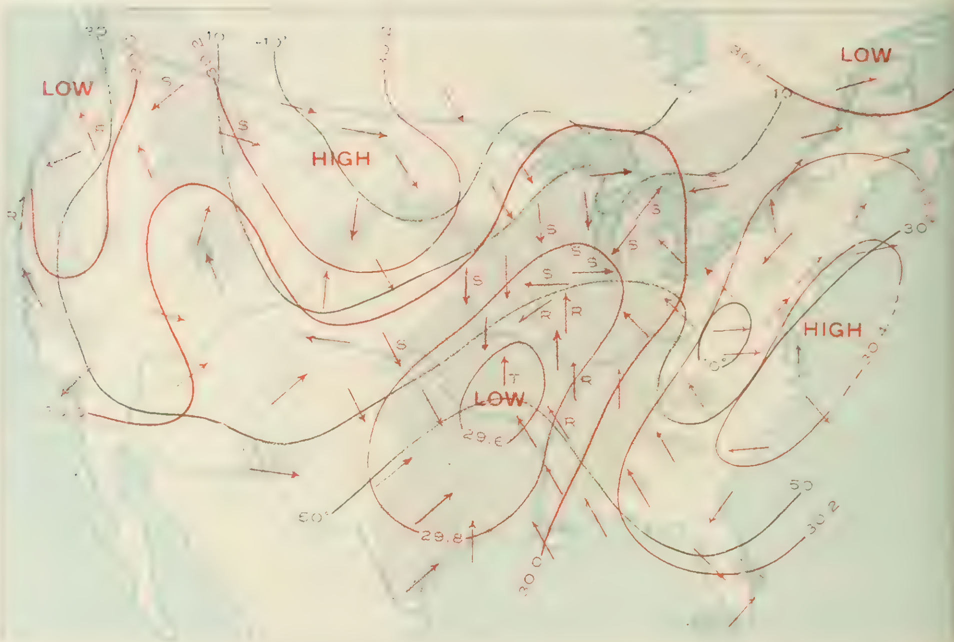


FIG. 110.—The Southwest Storm of December 12, 1903

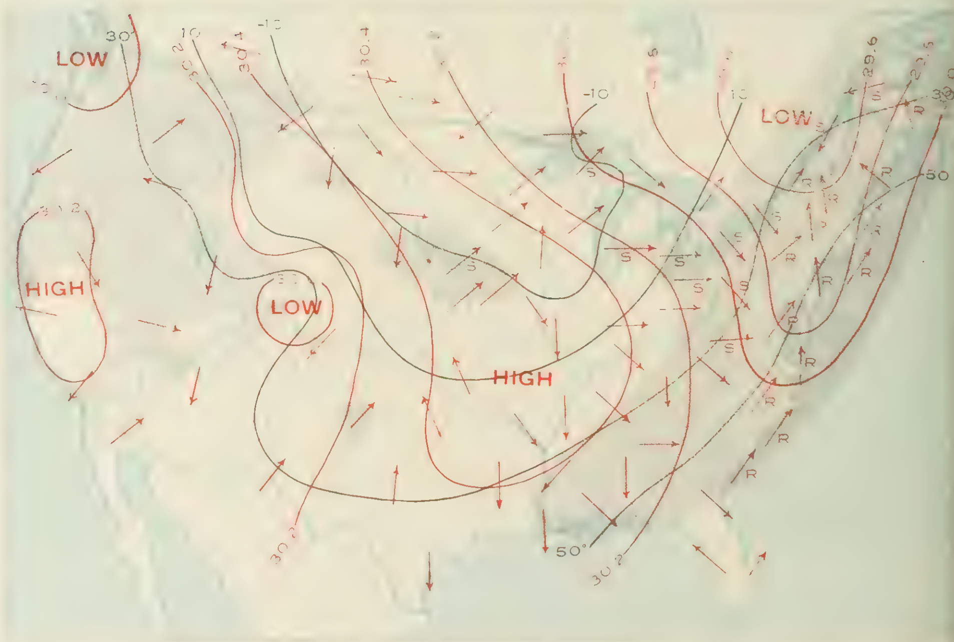


FIG. 111.—The Southwest Storm of December 13, 1903.

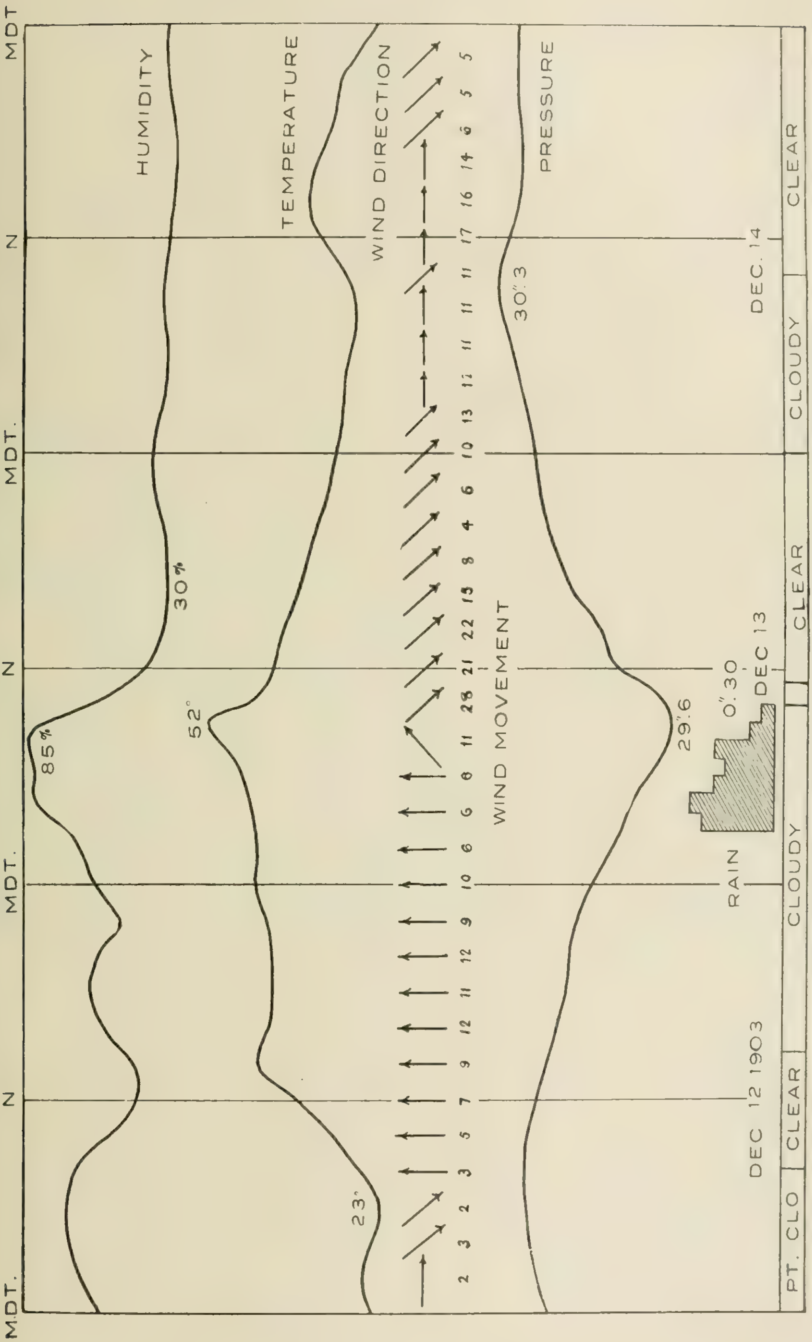


FIG. 112.—The Southwest Storm of December 12-14, 1903.

Bureau. A detailed presentation of the successive local changes during the 13th, as this storm traversed the horizon of Baltimore will be found in the accompanying diagram. It is also possible in this case to show the hourly changes in the relative humidity. At 8 a. m., with change of wind from south to southwest and then to northwest, there was a remarkably rapid change in the humidity, the decrease amounting to about 55 per cent in four hours. (See Figs. 110-112.)

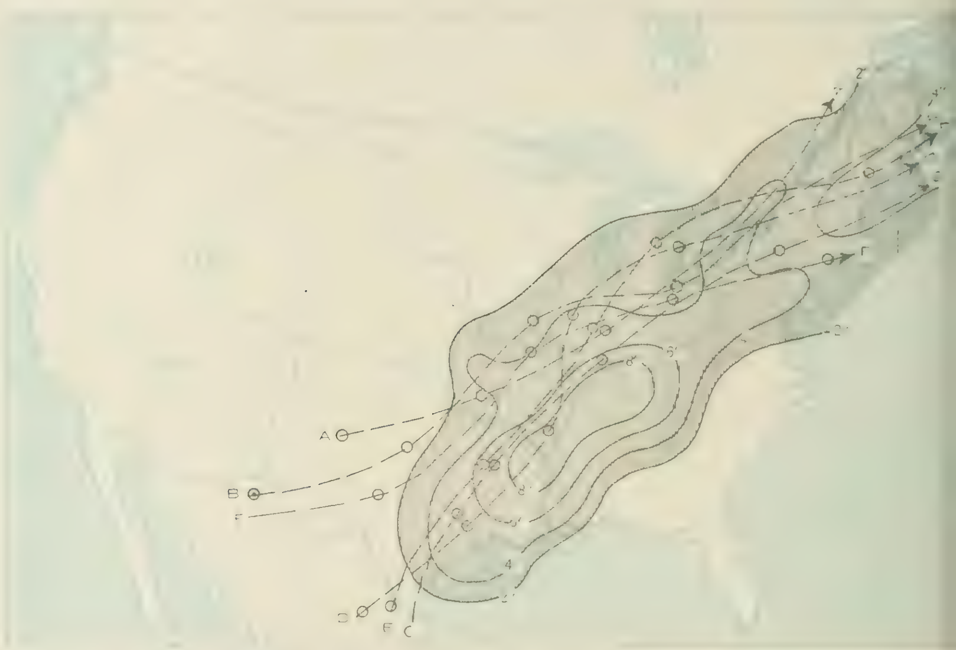


FIG. 113.—Paths and Rain Areas of Southwest Storms of January, 1898.

In the reports of the local office of the United States Weather Bureau the 13th is described as cloudy in the forenoon and clear in the afternoon. The temperature was very high in the morning, with a maximum of 52° about 8.30 o'clock. With a sudden change of wind at this hour from southwest, through the west, to northwest, a rapid fall in temperature took place (10° in the first hour), and it continued to grow colder to a minimum of 30° at midnight. The atmosphere was crisp and invigorat-

ing in the afternoon. A blustering wind prevailed in the forenoon. Light rain began during the night or early morning, and ended at 9.30 a. m. The total amount was 0.30 inch. The wind became brisk shortly after 9 a. m., changing to high westerly winds, and then to northwest, with a maximum velocity of 41 miles per hour at 9.30 a. m. A cold wave warning was received at noon, announcing a probable change of 20° to 30° before the close of the following day. Southwest storm warnings had been ordered up along the coast from Savannah to New York on the 12th; these were changed to northwest on the morning of the 13th.

These southwest storms are usually accompanied by large rain areas and heavy local rains. At times a series of these storms will follow one another in close succession, all taking approximately the same path, from Texas across the Lake region and New England, or the St. Lawrence Valley out into the Atlantic. A remarkable series of this kind was experienced during the month of January, 1898. The accompanying chart (Fig. 113) shows the paths of six storms of this type all occurring between the 8th and 26th of January, 1898, together with the total amount and distribution of precipitation recorded along the various paths. The rate of movement of the storms is shown by the circles along the lines illustrating the storm paths, the intervals representing periods of twelve hours.

THE GULF STORM.

Many of the storms which have their origin in the southwest or over the Pacific, and cross the country along the southwest path, continue their southeast course to the Gulf before recurving to the northeast. Some have their origin over the Gulf of Mexico and move northeastward to the Gulf of St. Lawrence. The path taken by these storms brings their centers very close to Baltimore. Sometimes the center of the barometric depression passes just to the west of Baltimore, sometimes to the east, and occasionally immediately over the city. They are usually accompanied by heavy precipitation, and by high winds along the coast. Very frequently these storms develop over the Gulf of Mexico while

an area of high pressure prevails over the New England states. Under the influence of this distribution of pressure, northeast to east winds set in over the Middle Atlantic states and southeast winds over the South Atlantic states. The rain area spreads rapidly northward and eastward under these conditions and reaches Baltimore while the center of the depression is still in the Gulf states.

The average winter temperature of Baltimore is close to the freezing point; hence slight changes in temperature will change the form of precipitation from rain to snow or from snow to rain, or to the disagreeable intermediate stage of sleet. As these Gulf storms are nearly always preceded by comparatively high temperatures and followed by temperatures below the freezing point, they are apt to cause much personal discomfort, with their rain, sleet, and snow, resulting in slushy or icy streets in the cities. Farther north the precipitation is mostly in the form of snow, and a short distance to the south it is all rain. The high winds which frequently accompany this type of storm not only increase the discomfort but add an element of danger.

The Storm of February 1-3, 1902.

(Center passes west of Baltimore.)

The weather map of 8 a. m., February 1, 1902, shows the prevalence of two well developed areas of high barometric pressure, one in the northeast, with its center over the Gulf of St. Lawrence, the other in the extreme northwest, centered over Idaho and Montana. In the Gulf states and in the Southwest the barometer was low, and unsettled weather prevailed from the Lake region to the Gulf, and from the Atlantic coast westward nearly to the Rocky Mountains. In the Atlantic coast states the barometric depression was already well developed, and rain was falling at 8 a. m. throughout the South Atlantic states, in Virginia, Maryland, and Pennsylvania, and snow in New York and the New England states.

As the storm moved rapidly northeastward it developed in intensity and in definiteness of outline, the rains became heavier and the area of precipitation increased. The high area over the Gulf of St. Lawrence

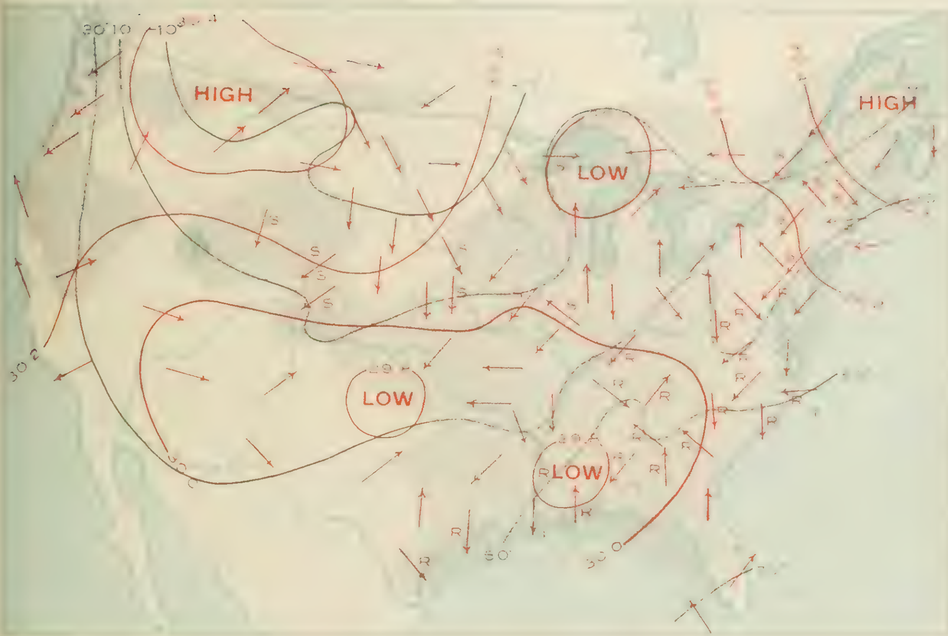


FIG. 114.—The Gulf Storm of February 1, 1902.

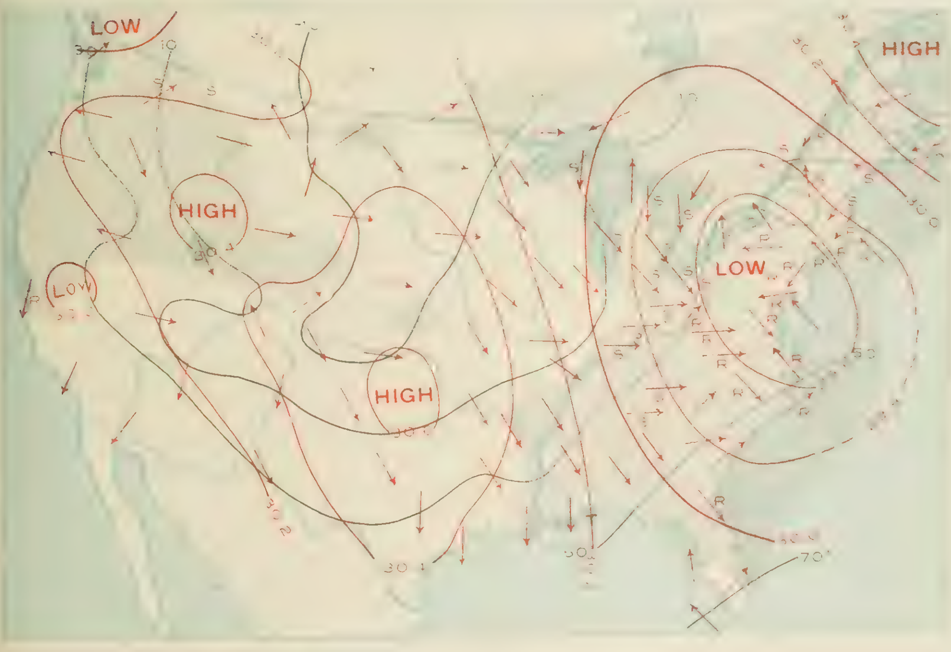


FIG. 115.—The Gulf Storm of February 2, 1902.

remained stationary while that in the extreme Northwest moved rapidly southeastward accompanied by a decided fall in temperature in the southwest quadrant of the storm area. At 8 a. m. of the 2d of February the area of lowest barometer was over Pennsylvania, the center of the storm having passed just to the west of Maryland during the preceding night. The center of the western high area was over Kansas and Oklahoma. During the preceding 24 hours a fall of 15° to 30° in tempera-

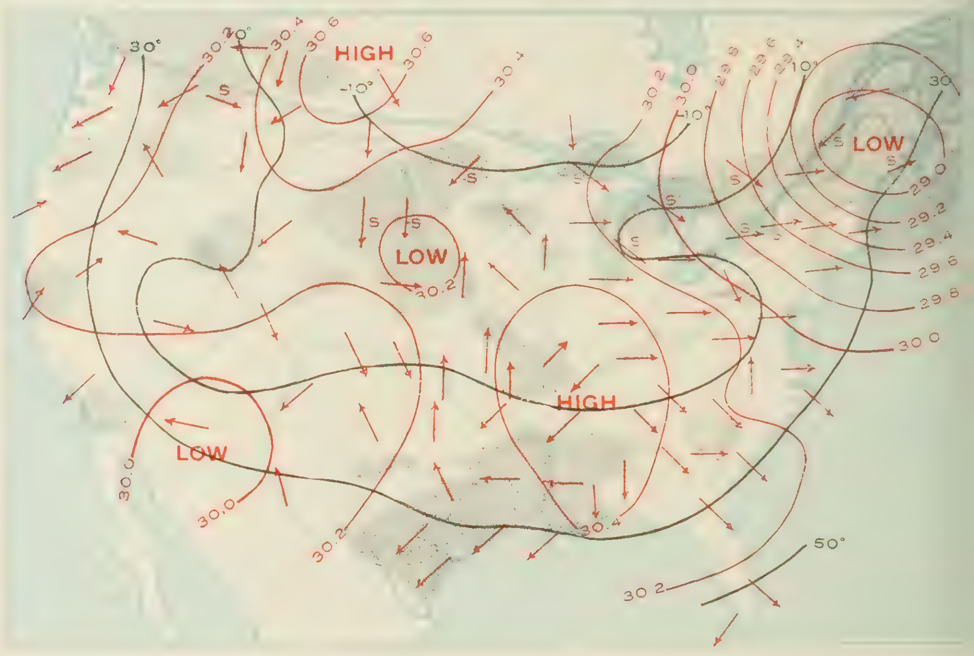


Fig. 116.—The Gulf Storm of February 3, 1902.

ture was experienced over a wide area from Iowa and Nebraska southward to the Gulf coast. High easterly winds prevailed during the night and early morning along the coast from the South Atlantic to the New England states. (See Figs. 114-117.)

By the morning of the 3d the storm center had moved to the New England states, the cold wave had reached the Atlantic coast from Florida to North Carolina, and had overspread most of Virginia, Maryland, and Pennsylvania. The local changes at Baltimore during the

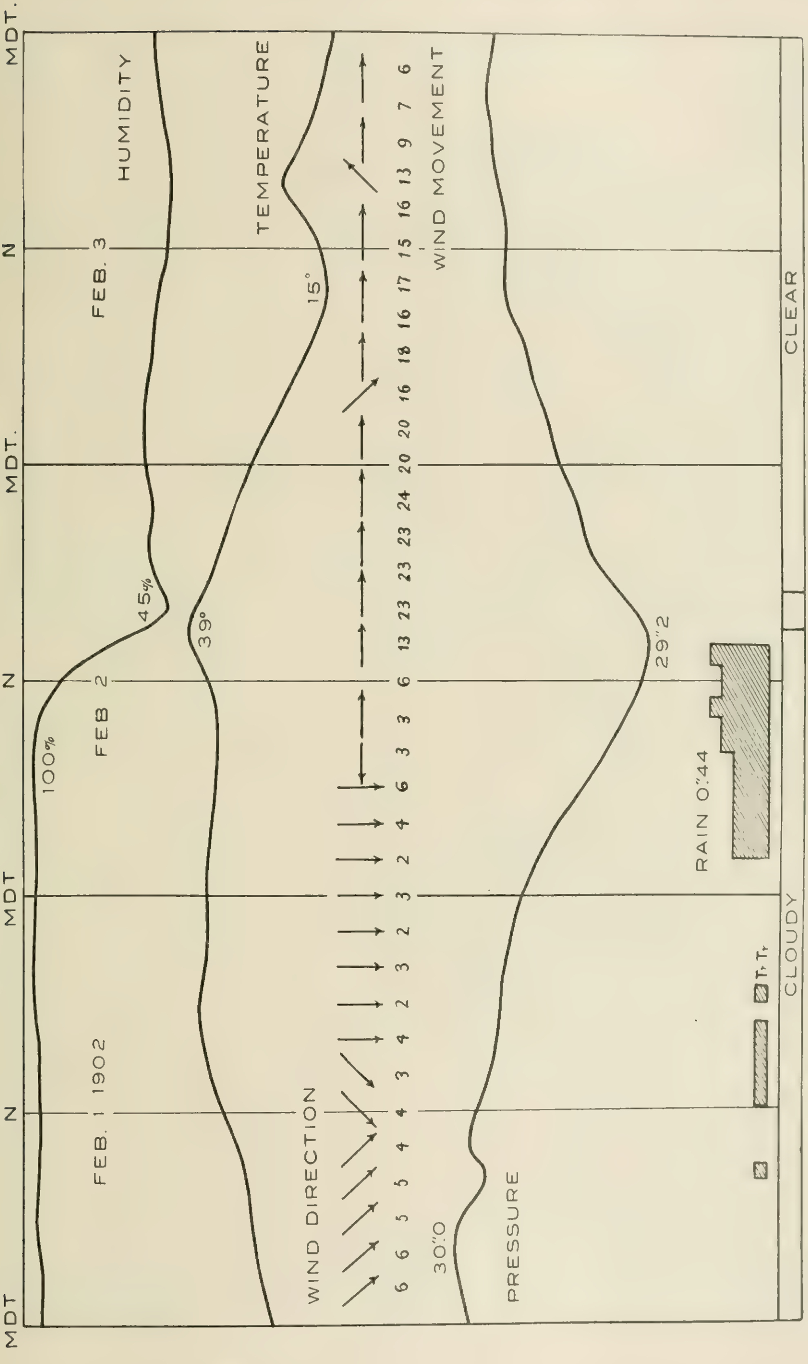


FIG. 117.—The Gulf Storm of February 1-3, 1902.

passage of this storm are indicated in the accompanying diagram, and in the following extracts from the daily journal of the Weather Bureau:

February 1, 1902. On February 1, while the center of the storm was over the Gulf States, the day was cloudy, the sky being continuously overcast. At 7.45 a. m. precipitation began in the form of sleet, turning in 10 minutes to a light misting rain. The winds were from northeast to north from noon to midnight, and very light, averaging but 3 to 4 miles per hour. Light rains continued at intervals until 8.40 p. m., the entire amount for the day being but 0.07 inch. The day was disagreeable; the sidewalks were icy. The maximum temperature of the day was 37° at 6 p. m. The barometer fell steadily throughout the day from 30.03 inches at 4 a. m. to 29.77 inches at midnight. The relative humidity was approximately 100 per cent all day.

February 2, 1902. The day continued cloudy during the forenoon. The temperature rose slowly to 39° at 2 p. m., while the barometer fell to 29.25 inches. The wind changed from north to east at 8 a. m. and to west at 10 a. m., and continued light in force. Early in the afternoon the wind began to increase in force, reaching a maximum of 33 miles per hour from the west between 4 and 5 p. m., shortly after the barometer began to rise. From 2 p. m. the temperature fell steadily to 15° at midnight of the following day. After an interval of several hours light rain began again between 2 a. m. and 3 a. m. and continued without interruption until about noon, becoming heavy at times. From noon to 1.40 p. m. the precipitation was a mixture of rain and snow, the snow melting as it fell. The total fall of rain and snow combined was 0.44 inch.

The day as a whole was extremely disagreeable. The sidewalks were icy and dangerous to pedestrians. In the forenoon the gutters and streets were filled with slush, which, as night approached, became frozen solid. Some damage was done to awnings, signboards, and chimneys by high winds. The wind, however, cleared the harbor of floating ice. Light fog prevailed during the preceding night and lifted at about 11 a. m. Northwest storm warnings were ordered up at 10 a. m. from Florida to Baltimore. A cold wave warning was received at 2.50 p. m., forecasting a fall to 15°, or below, in the interior of the State, and to 20° along the coast. The clouds disappeared rapidly after 3 p. m. and by 5 p. m. the sky was clear.

February 3, 1902. The day was clear and much colder than the 2d. The temperature fell to 15° at 9 a. m. There were no clouds excepting a few small cumuli in the afternoon. The wind continued brisk during the night, but diminished towards noon. Navigation was free on the western side of the Bay, but along the eastern shore the ice was piled up by the winds. All tributaries of the Chesapeake were frozen solid.

The Storm of January 5-7, 1905.

(Center passes over Baltimore.)

On the morning of January 5, 1905, a somewhat similar distribution of pressure obtained to that of February 1, 1902, described above. An

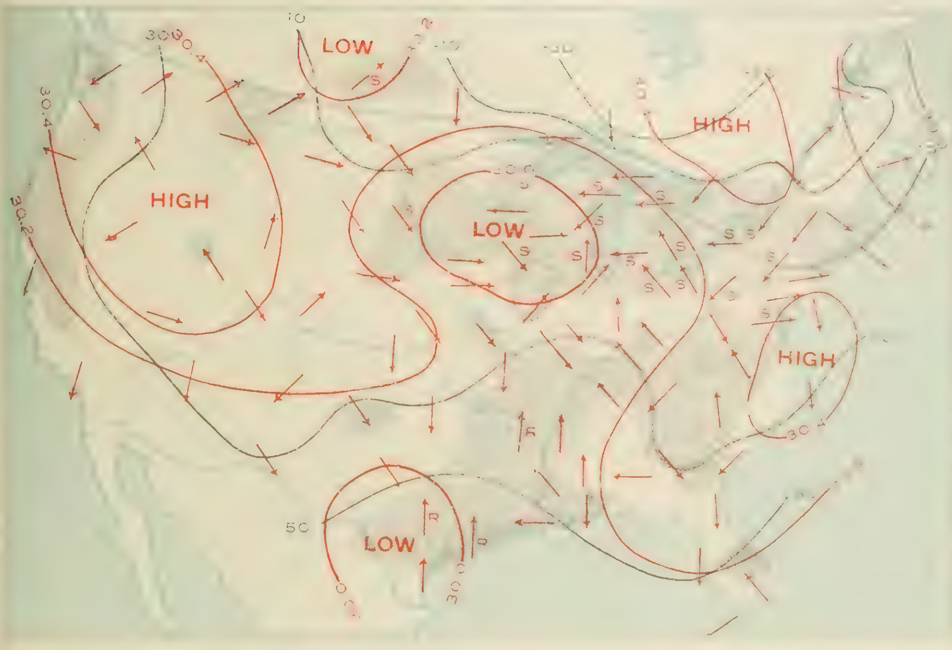


FIG. 118.—The Gulf Storm of January 5, 1905.

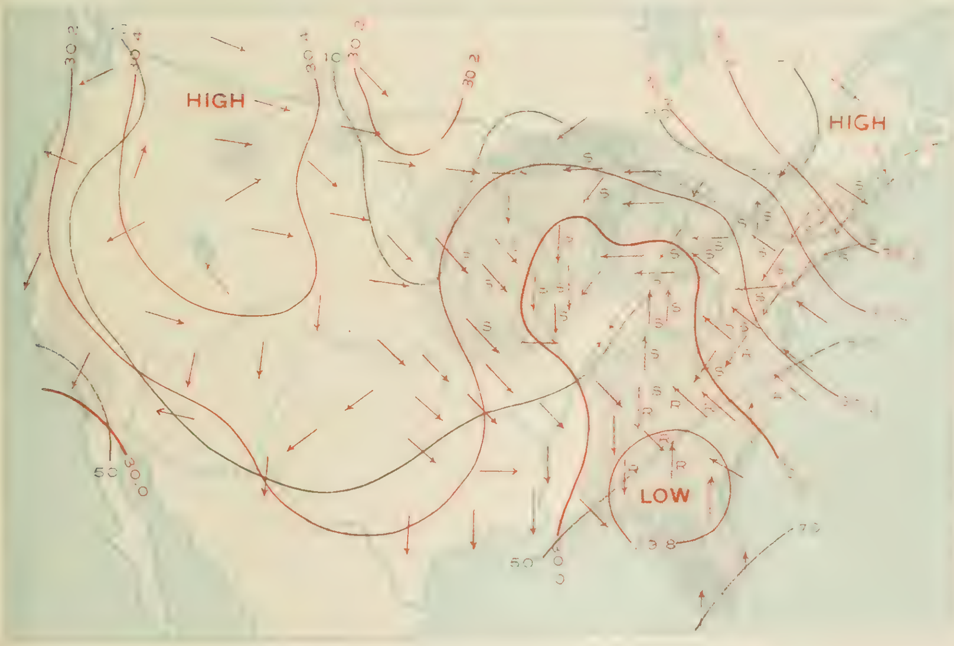


FIG. 119.—The Gulf Storm of January 6, 1905.

area of high barometer prevailed over the Atlantic coast states, and another over the Rocky Mountain Plateau. The pressure was low over the Mississippi Valley with a tendency to deepen over the Gulf states. By 8 a. m. of the following day the Atlantic coast area of high pressure had concentrated over the New England states, while the Rocky Mountain high area had changed but little in intensity or outline. The center of the barometric depression had been transferred to Northern Florida

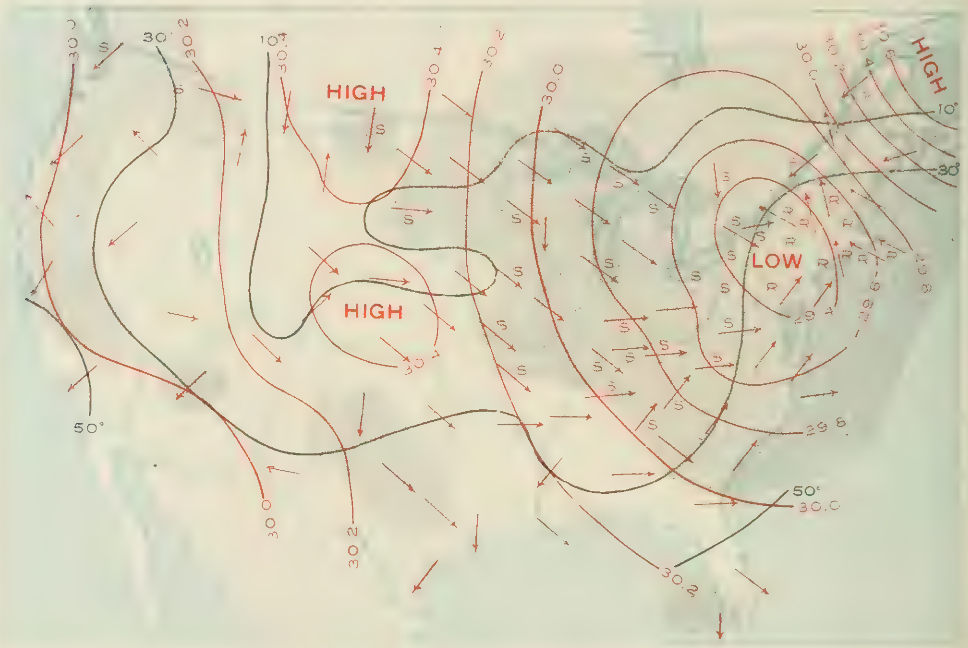


FIG. 120.—The Gulf Storm of January 7, 1905.

and Southern Georgia. This combination of pressure along the Atlantic coast always gives rise to northeasterly winds with a steady rain or snow. At 8 a. m. of the 6th rain was falling in the South Atlantic states and snow in the Middle Atlantic and New England states. The snow area also reached westward to the Ohio Valley and the Lake region in connection with the development of a secondary depression over Lake Michigan. (See Figs. 118-121.)

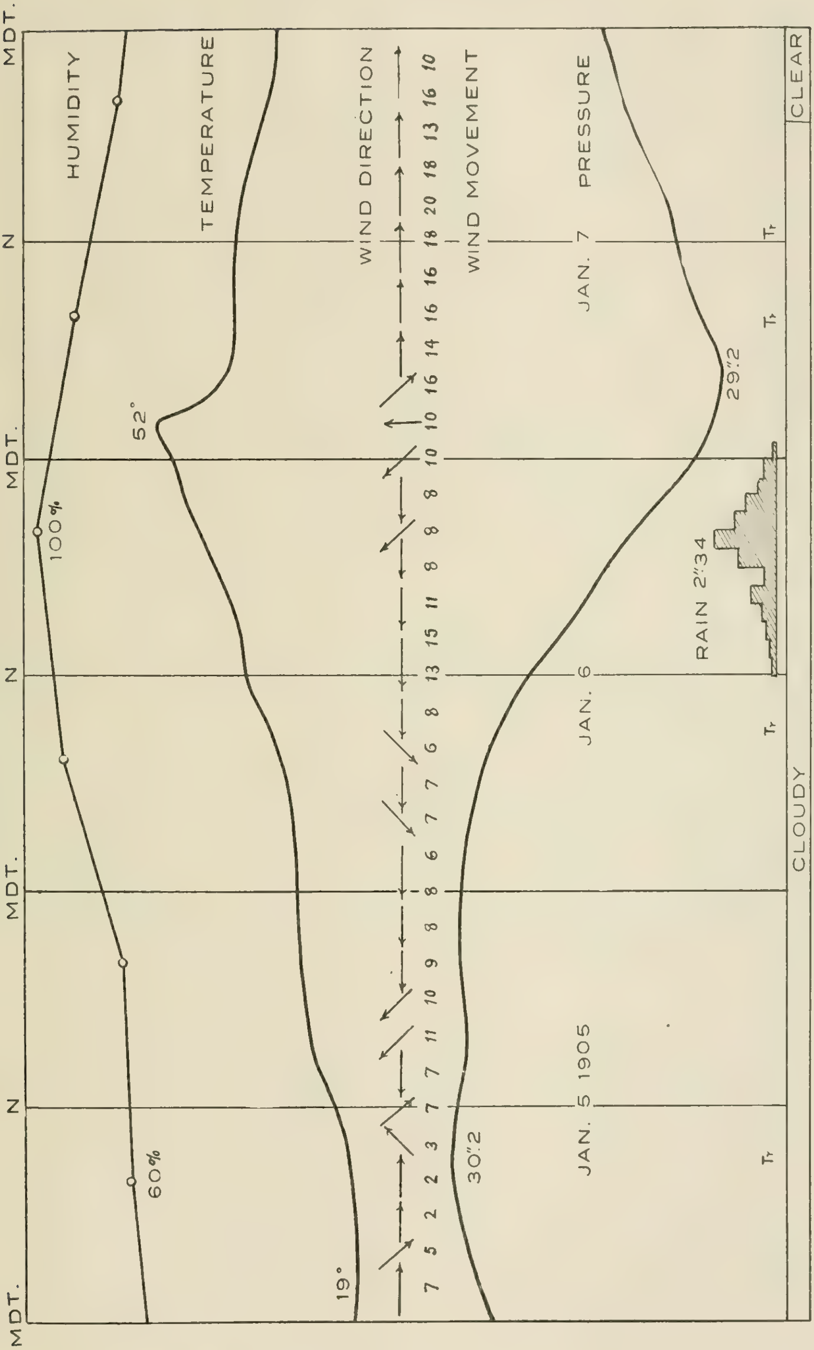


FIG. 121.—The Gulf Storm of January 5-7, 1905.

After reaching the coast the storm took a sharp turn northward, increasing in intensity as it followed the coast line. The center passed directly over Baltimore at about 4 a. m. of the 7th with an abrupt change in the direction of the wind from south to northwest, and a fall in temperature. The winds were light to fresh during the progress of the storm over Baltimore, only exceeding 20 miles per hour for a short time between 3 p. m. and 4 p. m. By the morning of the 8th the center had passed northward to the Lower St. Lawrence River.

The temperature rose rapidly 20° to 40° along the Atlantic coast in advance of the center of the storm, but fell more slowly after the center had passed, as the high area of the Rocky Mountain region was advancing but slowly eastward behind the storm. Heavy rains marked the spread of the storm in its eastern half all along the Atlantic coast; rains of one to two inches in 24 hours were reported from many of the Weather Bureau stations. The precipitation at Baltimore amounted to 2.34 inches during the 12 hours from noon to midnight of the 6th.

Some details of the local conditions at Baltimore are shown in the following extracts from the daily journal of the local office of the United States Weather Bureau:

January 5, 1905. A cold cloudy day. Light snow began at 8.30 a. m. and ended at 10 a. m. The winds were westerly in the forenoon and easterly in the afternoon.

January 6, 1905. The day was cloudy and somewhat warmer than yesterday. Light rain began at 8.55 a. m., ended at 9.10 a. m.; began again at 12.10 p. m. and continued to midnight. The rain was heavy from 7.40 p. m. to 7.49 p. m., 0.22 inch falling within the 9 minutes. The total precipitation for the day was 2.34 inches.

January 7, 1905. A cloudy day until 6.30 p. m.; the clouds broke away soon after and by 8 p. m. the sky was clear and remained so until midnight. The rain of the preceding night continued until 12.10 a. m. Rain began again at 6.40 a. m. and ended at 7.35 a. m.; began again at 8.50 a. m. and ended at 8.55 a. m. From 12.30 p. m. to 12.50 p. m. snow was mixed with rain. The total precipitation for the day was 0.02 inch.

A continuous record of changes in the meteorological elements at Baltimore is shown in the accompanying diagram. (See Fig. 121.)

The Storm of February 20-22, 1902.

(*Center passes east of Baltimore.*)

February, 1902, was remarkable for the number of Gulf storms experienced. In fact, these storms were a conspicuous feature of the entire winter of 1901-02. While the great majority of our storms follow the northern route across the Lake region in a normal winter,

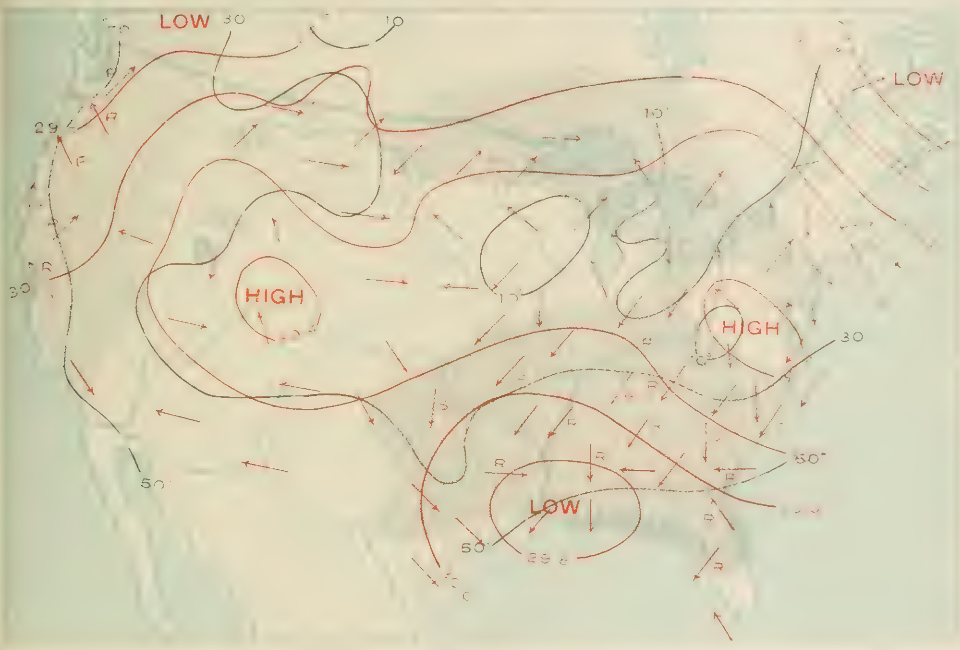


Fig. 122.—The Gulf Storm of February 20, 1902.

the storms of February, 1902, without exception, followed the southern path and crossed the horizon of Baltimore with remarkable regularity by way of the Gulf of Mexico. Occasionally there will occur a series of three or four storms in regular succession following this track. The area of cloudiness and rain accompanying a Gulf storm passes over a given locality in about two or three days; this is followed by four or five days of fair weather before the approach of another storm. During the winter of 1901-02 there was a remarkably regular succession of these

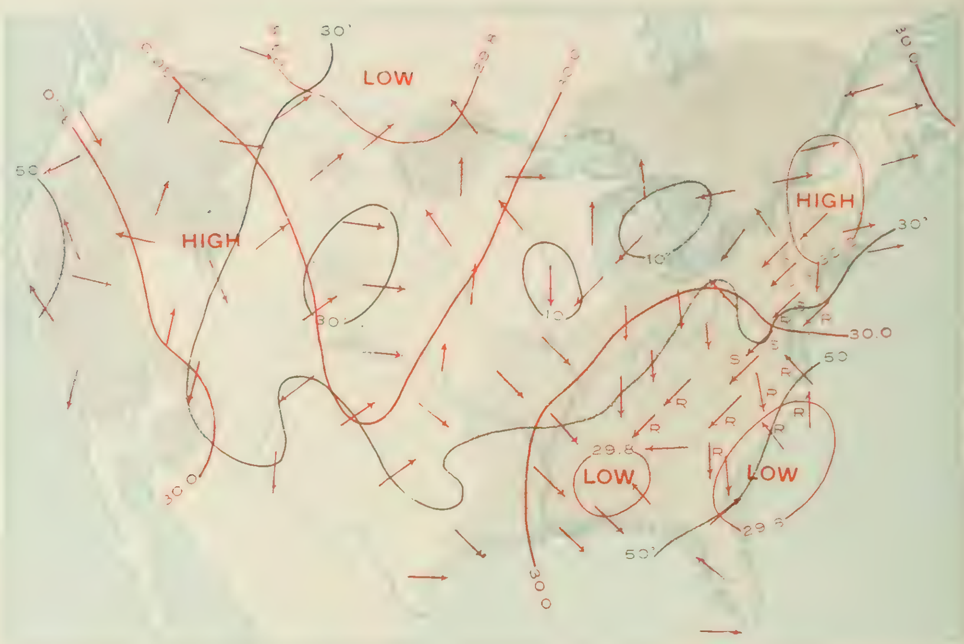


FIG. 123.—The Gulf Storm of February 21, 1902.

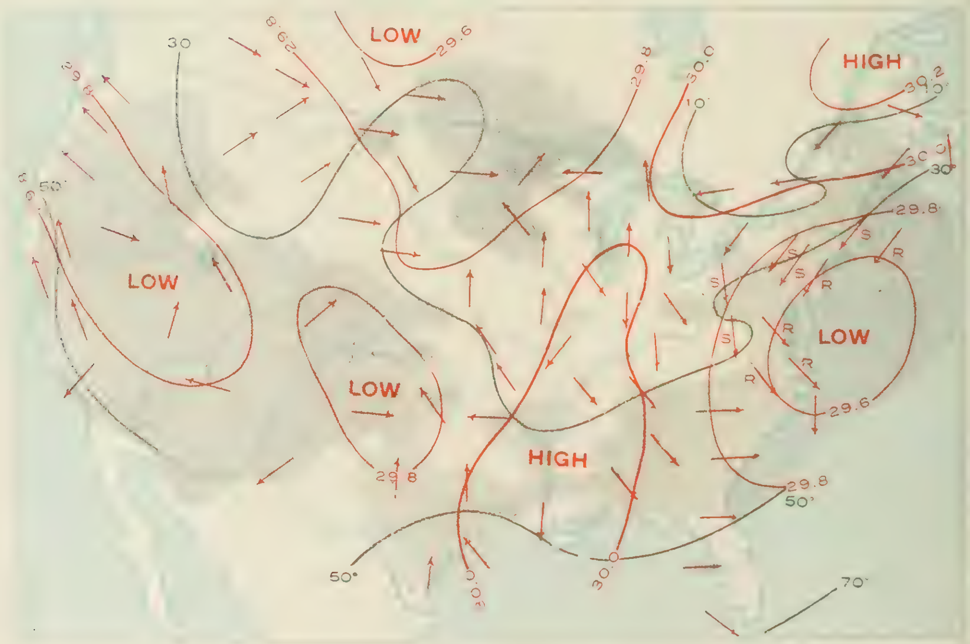


FIG. 124.—The Gulf Storm of February 22, 1902.

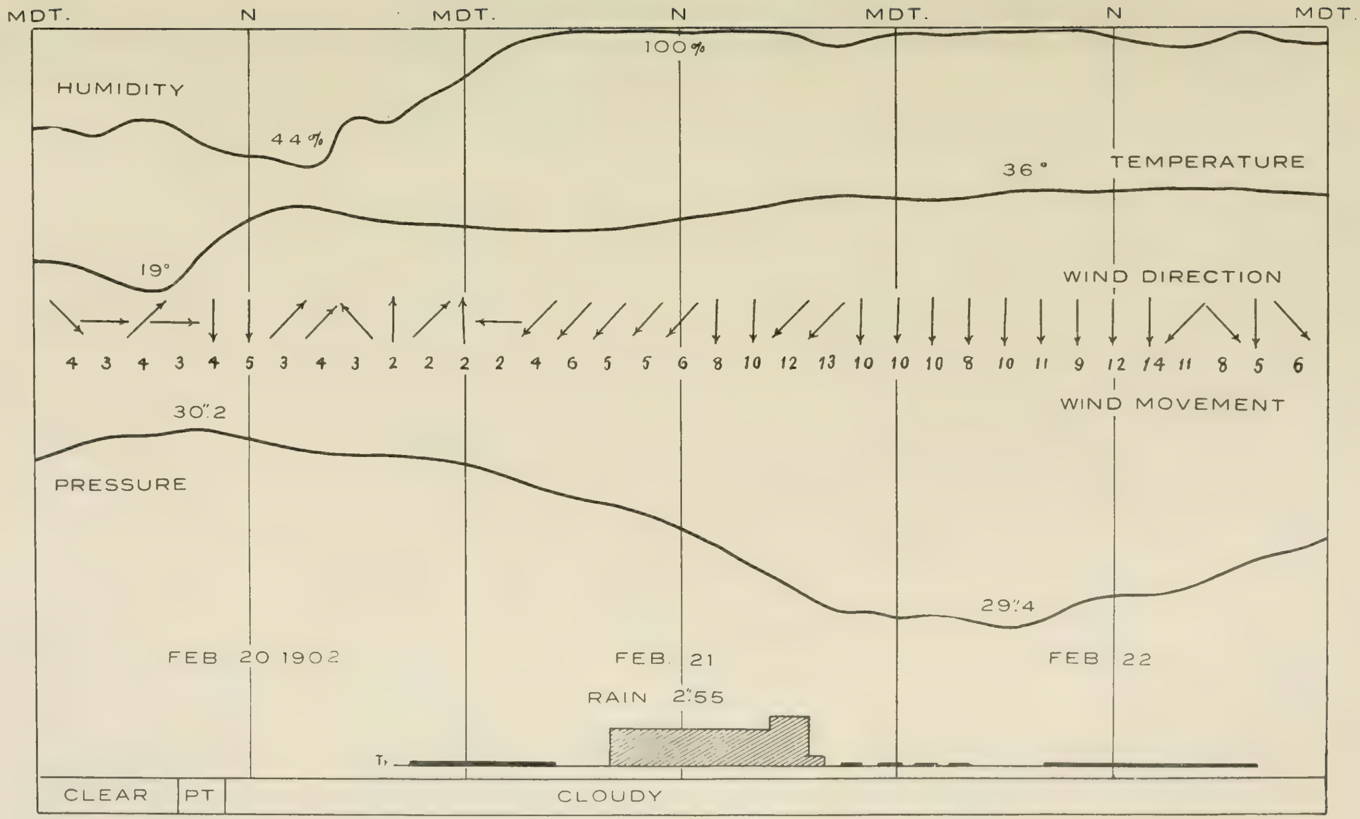


FIG. 125.—The Gulf Storm of February 20-22, 1902.

storms, the period of rain and succeeding fair weather covering seven days and causing the unusually long continued series of rainy Sundays so generally commented upon at the time. This is not an uncommon occurrence but the regularity of the succession was unusually well marked. (See Figs. 126 and 127; also Fig. 113.)

Why storms take this southern course with such unusual frequency at times it is difficult to say. Perhaps all that can be said in explana-

Fig. 126.—Normal Paths of Storms for February in Black. Average Path of Storms for February, 1902, in Red.

tion is that it is due to a departure from the normal conditions in the general circulation of the atmosphere—some unusual movement of the large persistent areas of high and low pressure referred to in an earlier paragraph.

One of the most notable of the series of Gulf storms referred to above passed over Baltimore on February 21 and 22, 1902—a storm which will long be remembered by Baltimoreans on account of the intensely disagree-

able combination of rain, sleet, snow, and high winds experienced. The storm originated off the North Pacific coast on the 17th, moved rapidly southeastward, reaching the Western Gulf coast on the morning of the 19th. Here it lingered for a day, increasing in intensity and enlarging its rain area. Moving eastward along the Gulf coast to the Atlantic, the center followed the coast northward, passing to the east of Baltimore during the day of the 22d, then out to sea. The presence of an area of high pressure to the northeast of the storm assisted in producing a steady north to northeast wind during the 21st. The official records of the Weather Bureau describe the local conditions as follows:

February 20, 1902. The day dawned clear and cold. A thin veil of cloud soon appeared, however, increasing in thickness as the day advanced, at

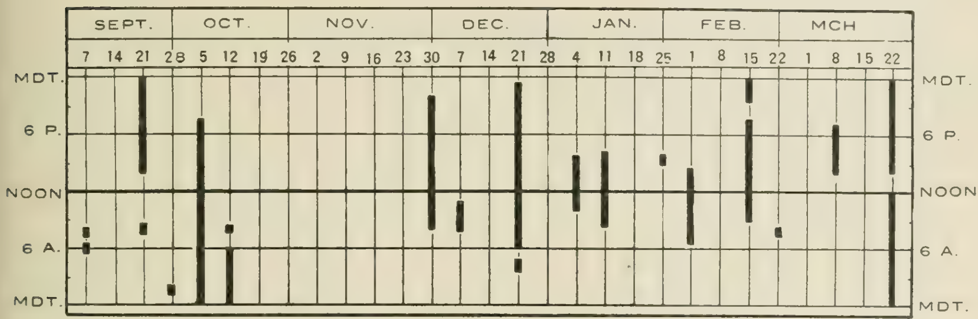


FIG. 127.—Diagram of Rainy Sundays of the Winter of 1901-2.

times becoming dark and threatening. The winds throughout the day were light and varying in direction between west and north, and changing to south in the evening. The temperature rose with the advance of the day, but barely reached the melting point of ice even at mid-day. Sleet began to fall at 8 p. m., turning to rain during the night. The barometer fell slowly but steadily throughout the day and night.

February 21, 1902. The rain of the preceding night froze as it fell, covering everything with a thick coating of ice. On trees, telegraph wires, and all exposed objects, the ice collected to a thickness of an inch or more, the heavy weight causing considerable damage. The rain continued with scarcely any interruption until 7.15 p. m.; at times it fell in torrents. Travel upon the streets became difficult and dangerous. The heavy rains of the afternoon converted the ice upon the streets into a heavy slush. The temperature remained nearly constant, varying but little from the freezing point of water. The winds were northeast to north all day, and increasing in force, not attaining a storm velocity, however. The barometer continued to fall

steadily and more rapidly toward night. The total precipitation for the day was 2.13 inches. The center of the depression was off the coast of North Carolina, the storm moving east of north and increasing in intensity.

February 22, 1902. A rainy day, with very little range in temperature, the maximum being 36° and the minimum 34°. The barometer reached its lowest reading at 6 a. m., rising slowly but steadily from this hour. Fresh northerly winds prevailed. The heavy rain of the preceding day turned to a mist at 11 a. m. and was accompanied by light flurries of snow between 3 p. m. and 6 p. m. At 7.20 p. m. a light moist snow began to fall, continuing at 8 p. m. The total precipitation of the day was 0.40 inch. The ice remained upon the streets most of the day in spite of the heavy rains and was a source of great discomfort. The heavy accumulation of ice caused much damage to trees and to telegraph and electric wires.

February 23, 1902. The day was clear and somewhat warmer than yesterday. The snow of the preceding night ended about midnight. The ice on the streets rapidly disappeared with the increased warmth. The day was pleasant and the atmosphere balmy.

Altogether this storm was one of the most disagreeable experienced in Baltimore. (See Figs. 122-125.)

THE BLIZZARD.

When storms such as have been described in preceding paragraphs are accompanied by heavy snow, high winds, and a temperature well below the freezing point, they are popularly known as blizzards. This type of storm is fortunately of infrequent occurrence in the Middle Atlantic states. When they have occurred it has been in connection with a Gulf or Southwest storm. An invariable accompaniment of the blizzard is the presence of an excessively developed area of high barometric pressure following in the wake of the depression, causing a steep barometric gradient and feeding into the storm center with great energy the cold westerly winds of the anti-cyclone.

Two storms of this type are especially worthy of consideration at some length owing to their exceptional severity all along the Atlantic coast—one is known as the blizzard of March, 1888, the other as the blizzard of February, 1899. The former, while occurring in March, is a marked instance of "winter lingering in the lap of spring."

The Blizzard of March 11-13, 1888.

The daily weather charts of the Weather Bureau for March 11, 1888, show the existence, in the morning, of an area of high pressure (anti-

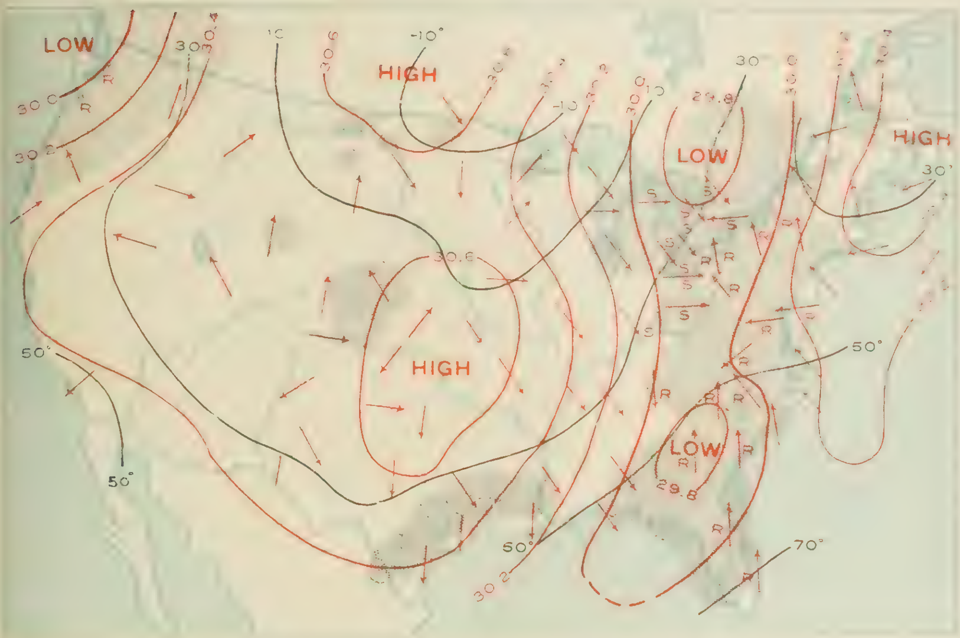


FIG. 128.—The Blizzard of March 11, 1888.

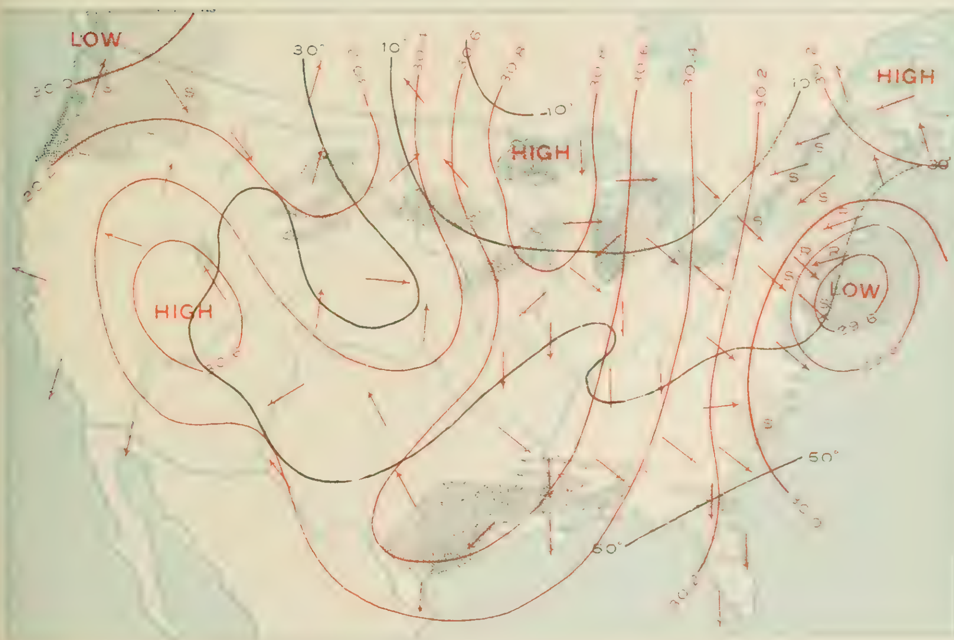


FIG. 129.—The Blizzard of March 12, 1888.

cyclone) centered over New England, and another of unusual extent and energy west of the Mississippi River with its center over the Southern Rocky Mountain slope. Between these two anti-cyclones there was a pronounced trough of low pressure extending from Lake Huron to Florida. Strong east to southeast winds prevailed in the Atlantic coast states with heavy rains, excessive in the South Atlantic states, and with temperatures varying from 30° in New England to 60° in South Caro-

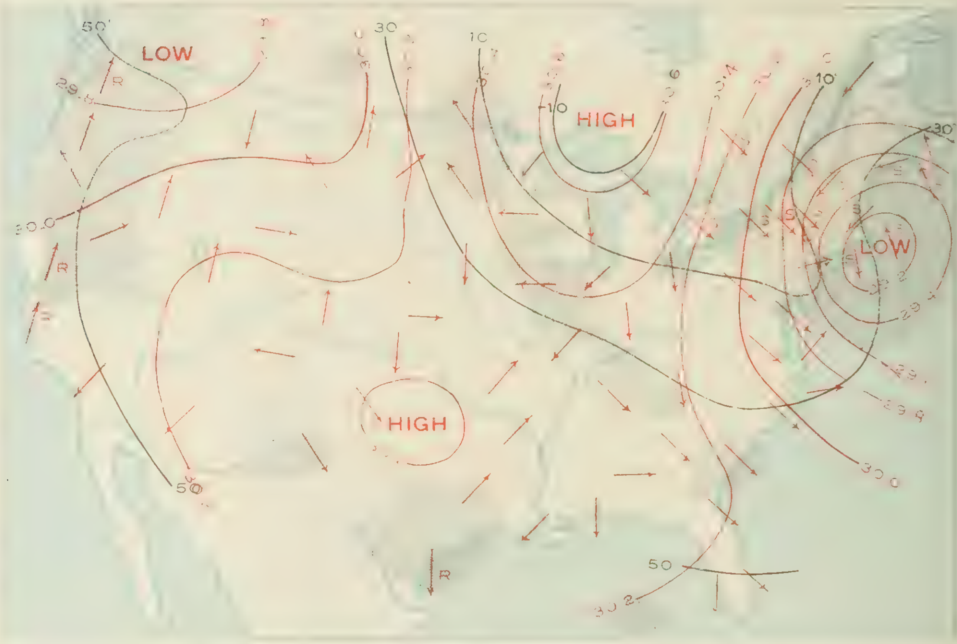


FIG. 130.—The Blizzard of March 13, 1888.

lina. To the westward of the trough of low pressure, the winds were from the west or northwest, with snow in the Lake region and Ohio Valley, and rain farther south. The barometric gradients were steep, and the temperatures fell rapidly toward the northwest, ranging from 50° above zero in Georgia to 20° below zero in Northern Minnesota. As the storm moved eastward the trough of low pressure changed to a well developed elliptical depression, with its center off the coast of Hatteras by 10 p. m. of the 11th; at the same time the storm was increasing

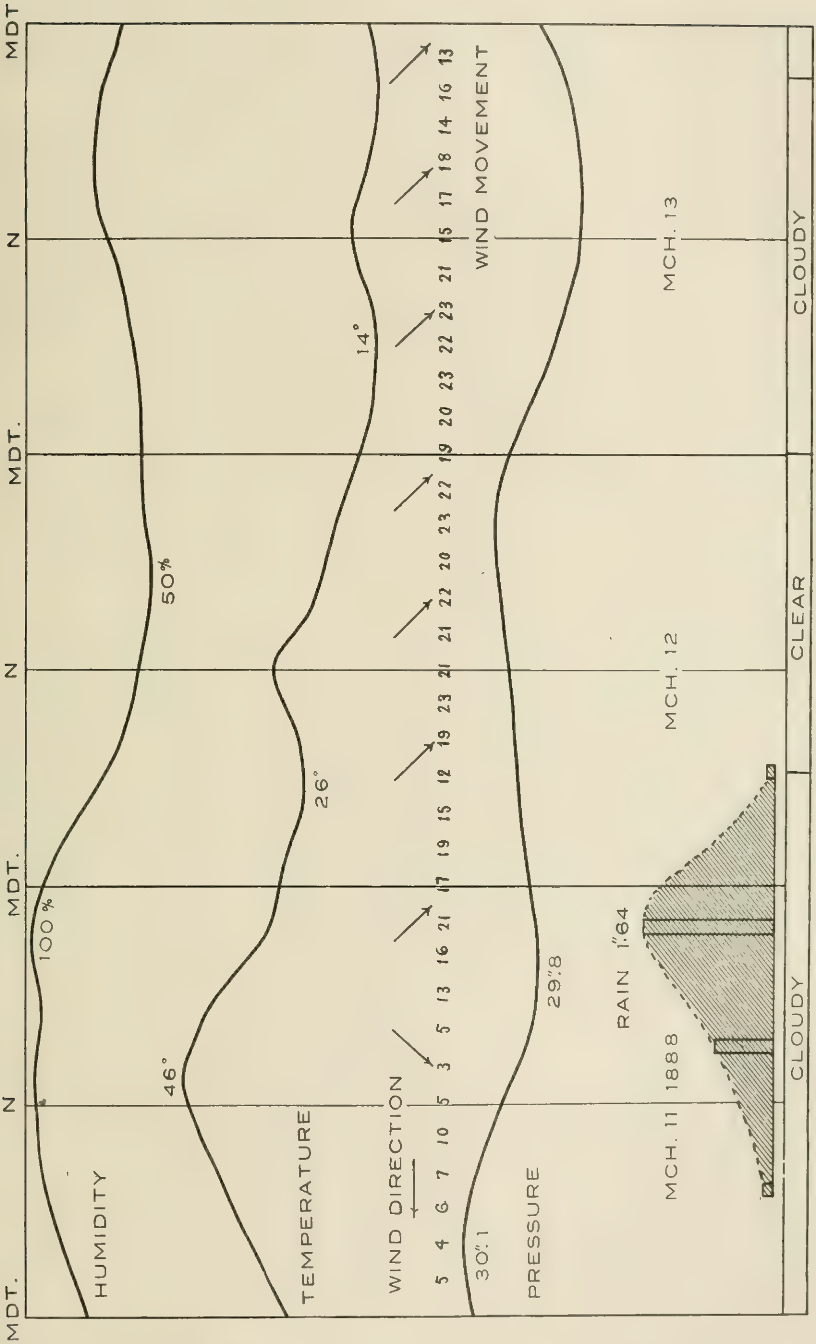


Fig. 131.—The Blizzard of March 11-13, 1888.

in intensity, causing high and destructive winds along the Middle Atlantic coast. The center of the storm moved northward near the coast, the high easterly winds of the 11th giving way to high off-shore winds by 7 a. m. of the 12th. The precipitation continued heavy in the form of snow in the Middle Atlantic and New England states. The cold wave had reached the Atlantic coast from New England to Virginia by the morning of the 13th. The center of the storm remained off the coast of Massachusetts for 24 hours and then moved eastward over the Atlantic. The snowfall over the southern portion of the New England states was unprecedented in the annals of that section. The heavy snows and high winds attending this storm caused serious interruption to telegraphic and railway communication in the Middle Atlantic and New England states from the 11th to the 15th of the month. (See Figs. 128-131.)

The storm passed over Baltimore on the 11th and the early morning of the 12th. The following paragraph is copied from the local official records:

> Light rain fell at intervals until noon of the 11th, then heavy rain until 6.50 p. m., when it changed to snow, accompanied by high northwest winds. In a short time telegraphic communication was cut off with nearly all points. The snow storm ended during the night of the 11th-12th and was followed by cold weather. The wind continued from the northwest throughout the 12th, attaining a maximum velocity of 40 miles per hour, and causing the lowest tide in many years, the bottom of the harbor being exposed in many places. This severe storm caused an almost entire suspension of business on the 12th. Reports from the surrounding country and from the Chesapeake Bay show the storm to have been very severe, and many vessels arriving on the 14th and 15th reported having experienced remarkably rough weather. The tide in Baltimore harbor did not resume its normal height until the 16th.

The Blizzard of February 12-14, 1899.

This storm was probably the most remarkable in the history of Baltimore. The amount of snow on the ground at the close of the storm was the greatest noted in the official records of the local Weather Bureau Office while the intense cold just preceding the snow storm lowered all existing official records. The winds maintained a storm velocity for more than 48 hours.

The cold wave which preceded the blizzard was one of the most wide-

spread as well as one of the most severe experienced in the United States, covering the entire country east of the Rocky Mountains to the Atlantic coast, and from the Lake region to the Gulf of Mexico, from the 9th to the 12th.

The distribution of atmospheric pressure over the northern hemisphere during this period, with accompanying weather conditions, was of peculiar interest and great significance. On the 10th of February practically the entire North American continent was covered by an area of high barometric pressure (an anti-cyclone) with a pressure of over 31 inches at the center, just north of Montana, a pressure only occasionally recorded. The degree of cold experienced near the center of this area (65° below zero) was exceeded but once in the official records of the Weather Bureau. Upon the same day a barometric depression (a cyclone) of great intensity covered the North Atlantic Ocean, with its center along the same parallel of latitude (50° north) and just west of the British Isles. This situation gave to Southern England a strong southerly wind which raised the temperature in London to 65° above zero, a degree of heat not experienced in February in a hundred years of recorded observations. Thus upon the same day and along the same parallel of latitude there was a difference of 130° Fahrenheit. The contrast was even more marked in the United States. While the minimum of 65° below zero was being experienced in Western Montana, the temperature in Western Washington (just across the Rocky Mountains, a distance of less than 300 miles) was 63° above zero, a difference of 128°.

This anti-cyclone, or cold wave, which overspread the United States from the 9th to the 11th of February, caused heavy snows to the southeast, along the line of advance. By the morning of the 12th a barometric depression began to develop over Northern Florida, and heavy snow was falling in the Gulf states, the South Atlantic, Middle Atlantic, and Southern New England states, with fresh to brisk north to northeast winds and falling temperature. At the same time the anti-cyclone in the west, maintaining its severity, was moving southward and eastward. By the morning of the 13th the center of the depression, which formed over Florida on the preceding day, moved northward along the coast,

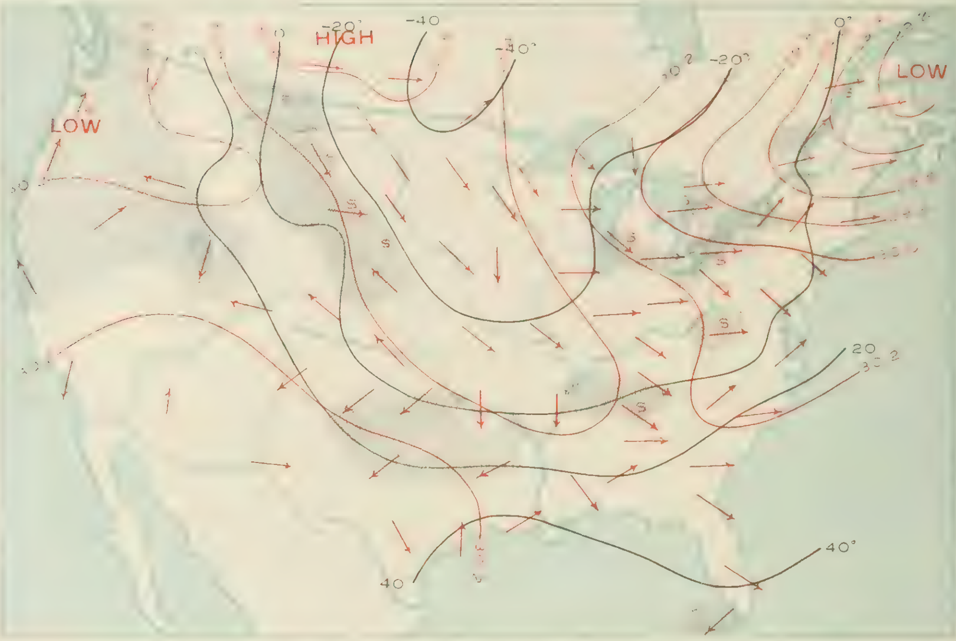


FIG. 132.—The Blizzard of February 9, 1899.

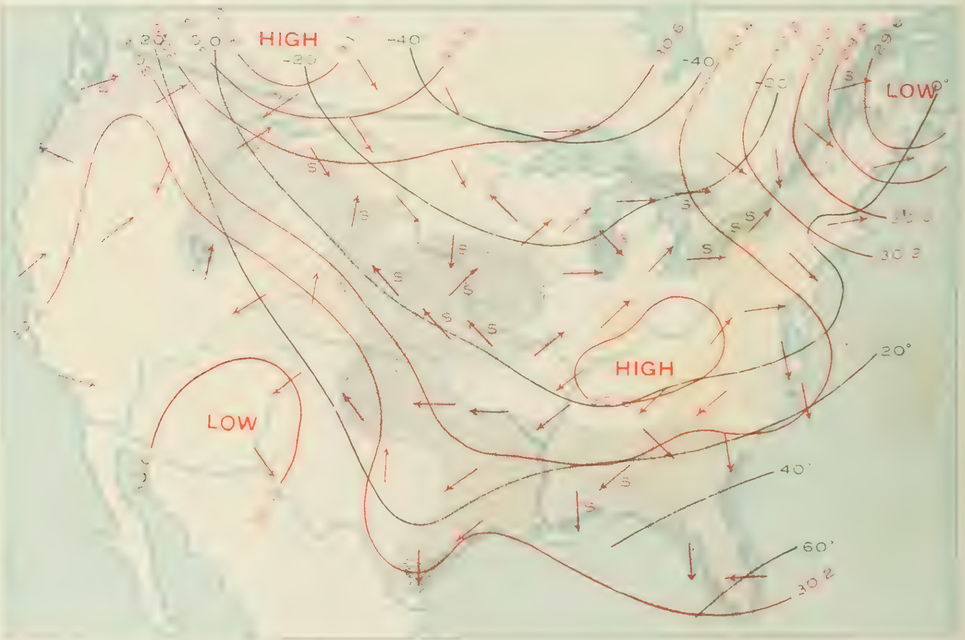


FIG. 133.—The Blizzard of February 10, 1899.

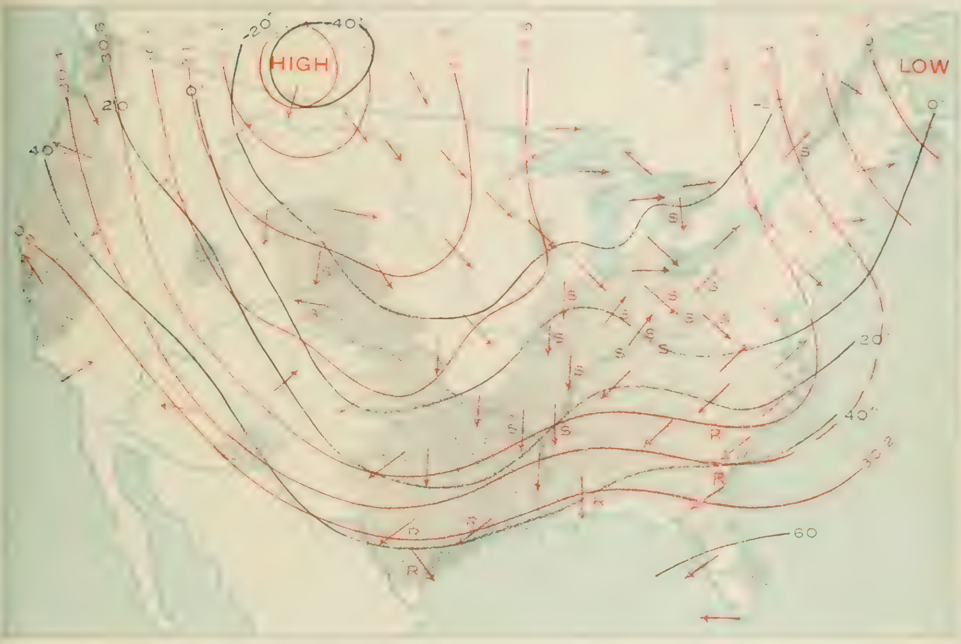


FIG. 134.—The Blizzard of February 11, 1899.

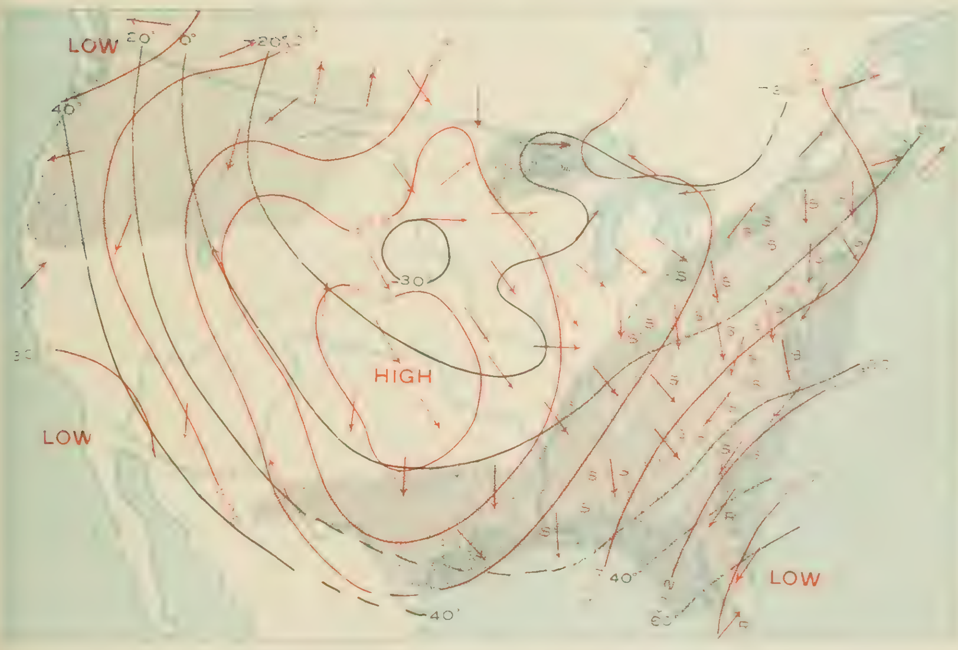


FIG. 135.—The Blizzard of February 12, 1899.

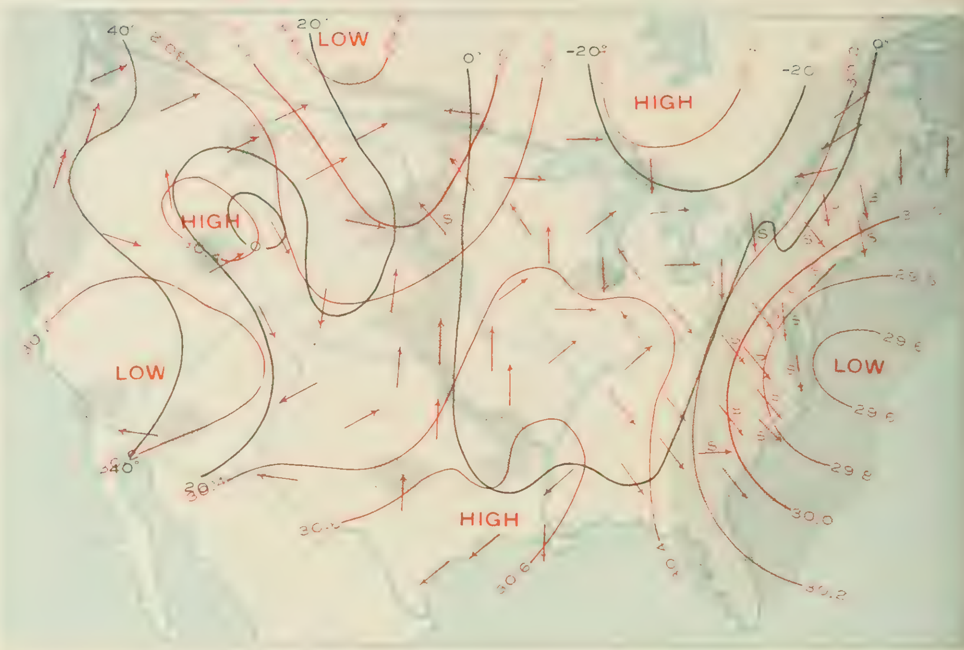


FIG. 136.—The Blizzard of February 13, 1899.

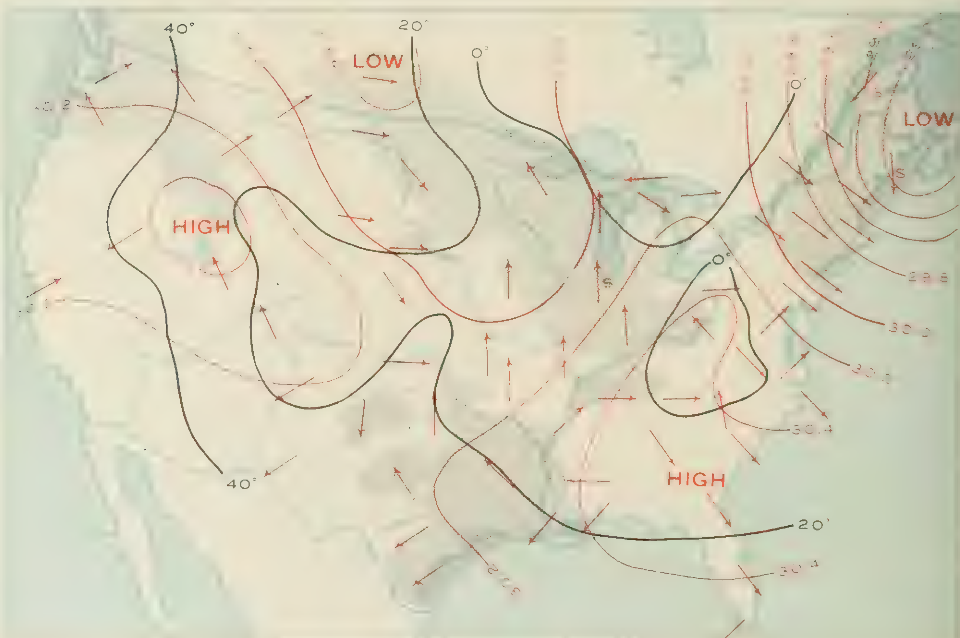


FIG. 137.—The Blizzard of February 14, 1899.

increasing in intensity and causing high northwest winds and heavy snowfall. The center of the storm crossed the latitude of Baltimore during the day of the 13th (Monday), just off the coast. The fall of snow during this day was the heaviest recorded in Baltimore in a 24 hour period. The temperature during the entire day did not exceed 10° above zero, while the northwest wind blew a gale. During the following day the storm continued its course northeastward along the coast

Fig. 138.—Snow on the Ground after the Blizzard of February, 1899.

and out over the Atlantic Ocean by way of the Grand Banks of Newfoundland. (See Figs. 132-138.)

The local conditions of the weather during the passage of the cold wave and blizzard described above are indicated in the following extracts from the daily journal of the office of the Weather Bureau, and in the accompanying diagram based upon the records of the self-registering instruments:

February 9, 1899. The day was clear and much colder than that of the 8th. The maximum temperature of the day was the lowest maximum re-

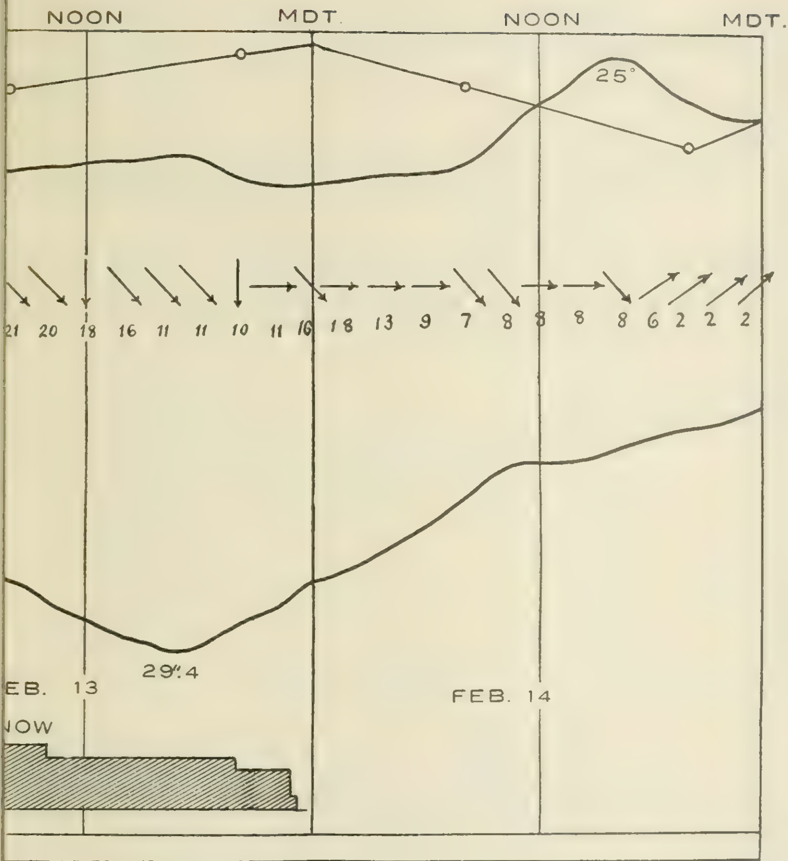
corded in Baltimore, namely 7°. There was a light fog in the morning. The winds were brisk to high, reaching a maximum velocity of 25 miles per hour. At 8 p. m. snow covered the ground to a depth of 11.3 inches. The ice in the harbor has increased in thickness to two inches.

February 10, 1899. A clear day. Severe, cold weather. The maximum temperature was 3°, the minimum 7° below zero, the mean 2° below zero, the lowest in the official records for the maximum, minimum, and mean for a day. Much suffering resulted from the intense cold. Several mortormen were overcome, and were revived with difficulty. A number of persons were picked up out of the snow drifts benumbed and unconscious. The suffering among the poor was very great. A series of accidents followed the sudden thawing of water in the water pipes when fires were started in the morning. Ten inches of snow covered the ground at 8 p. m., and the ice in the harbor increased to six and eight inches in thickness. The two ice boats were busy all day in their attempts to keep the channel clear, but the ice formed almost as fast as it was broken.

February 11, 1899. A clear day. The minimum temperature was 6° below zero. A light fog prevailed in the morning. Light snow began to fall at 5.35 p. m. and continued into the night. The snow on the ground at 8 p. m. was 9.7 inches in depth. There continues to be much suffering from cold, and one death from exposure is reported.

February 12, 1899. A cloudy day, with slowly rising temperature. Northeast storm warnings were ordered up in the forenoon. The following telegram was received from the Central Office in Washington: "Heavy snow is indicated this afternoon and to-night. Notify railroads and transportation companies." The snow which began yesterday at 5.35 p. m. became heavy at 8.15 p. m., then changed again to light snow during the night. It continued throughout the day. About five inches of snow fell during the day; the depth of snow on the ground at 8 p. m. was 14.5 inches. The weight of the snow had crushed a number of small sheds and a few wooden structures. To-day the President Street freight sheds gave way, owing to the accumulation of snow on the roof, and about 300 feet of the building fell; the damage amounted to about $20,000. The ice in the harbor is 6 to 8 inches thick. Navigation is practically suspended. Only heavy steel steamships are able to move. Trains are late and irregular. Much suffering continues among the poor.

February 13, 1899. A cloudy day. Heavy snow fell all day; the 24-hour fall was 15.5 inches. The depth of snow on the ground at 8 p. m. was 30 inches, the greatest recorded in the official records. Brisk to high north to northwest winds attained a maximum velocity of 28 miles per hour. The continued high blustery winds and the increasing snowfall combined to produce a typical blizzard. Railroad traffic was interrupted at an early hour. The street railways struggled to continue service, but the lines closed one by one, and none were in operation by nightfall. Much suffering continues. At least a score of people were overcome by the cold during the day. Birds are reported perishing in large numbers from cold and lack of food.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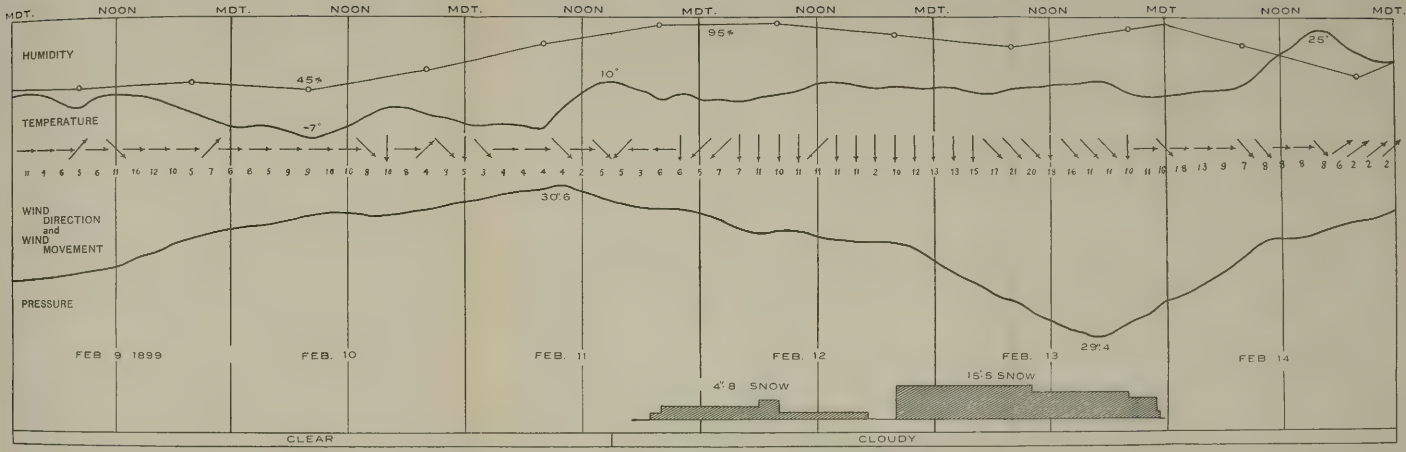

HOURLY OBSERVATIONS AT BALTIMORE DURING THE BLIZZARD AND COLD WAVE OF FEBRUARY 9-14, 1899.

February 14, 1899. A cold day with bright sunshine. Snow ended at 11.10 p. m. yesterday; one inch of snow was recorded this morning. Total snow depth at 8 p. m., 28 inches. The ice in the harbor is 10 inches thick. The city is practically snowbound. There was no mail delivery, no railroad movement, no street car service. Some vessels forced their way out of the harbor, but they were few in number. Much work is being done by the city and railroad authorities on the streets and lines of travel, but traffic was only partially restored. Much suffering continues. One man was found frozen to death this morning within six doors of his home. A milk famine is threatened. There has been a general rise in the price of commodities, especially of country produce. The Merchants and Miners Transportation Company lost the steamship Texas this morning. The vessel was run ashore in an ineffectual attempt to force a way through the ice and sank.

February 15, 1899. A clear day. Light fog in the morning. Street car service was resumed to-day in part. Trains are beginning to run on time. The ice in the harbor is one foot thick. The ice boats have succeeded in keeping a clear channel of 50 feet width. Four arrivals of vessels and one departure are reported for to-day. Snow on ground at 8 p. m., 26 inches.

Areas of Fair Weather (Anti-cyclones).

In the preceding pages the cyclonic type—or unsettled weather—has been described in considerable detail. The characteristic conditions of this type are cloudiness, rainfall or snowfall, brisk to high winds, a relatively high temperature, and a low barometric pressure, with winds converging toward the central area of low pressure.

In the Middle Atlantic states the cyclonic type dominates the weather conditions somewhat less than half the time, basing the calculation upon the number of days in the year during which some rain or snow falls. The annual number of days with precipitation at Baltimore has varied from 114 to 224 with a mean of 170. This implies that during somewhat over half the year the anti-cyclonic, or fair weather type, prevails. The chief characteristics of anti-cyclonic areas are: Barometric pressure higher than that over surrounding areas; a system of comparatively light winds, diverging from the central portion of the area; comparatively clear skies; and relatively low temperature. (See Figs. 85 to 89.)

High areas, or anti-cyclones, have already been described incidentally in the preceding discussion of storms. They are most numerous and more intensely developed during the winter season, when they move in rapid succession from the central continental areas, in the extreme Northwest,

along the eastern slope of the Rocky Mountains, eastward or southeastward across the United States.

When these areas grow to unusual proportions and develop a barometric pressure greatly in excess of the pressure in areas along their line of eastward progress, they constitute our "cold waves." There is no sharp line of separation, however, between the cold wave and the winter anti-cyclone—no more than there is between the storm and the barometric depression technically known as the cyclone. The anti-cyclone attains its greatest severity when a barometric depression develops in advance of it, causing an energetic inflow of cold northwest winds into the western portion of the depression. In area and in rate of movement the cyclone and anti-cyclone resemble one another; in the character of attendant weather conditions they are in most respects the exact opposite.

The difference in the character of the weather prevailing over cyclonic and anti-cyclonic areas is strikingly exhibited in the weather chart for the 2d of February, 1902, reproduced in Fig. 115, showing the actual condition of the weather at 8 a. m. as reported by the observers of the United States Weather Bureau in all parts of the United States and Southern Canada. (See also Fig. 89, page 325.)

A storm, or cyclone, of great extent and energy prevailed over the eastern portion of the country, with its central area of low barometric pressure over Pennsylvania and Maryland. The area of clouds extended from the Atlantic Ocean westward to the Mississippi Valley, and from the Great Lakes southward to the Gulf coast. The region over which rain or snow was falling at the time of observation, 8 a. m., while more limited in extent still covered a considerable area, comprising practically all of the New England and Middle Atlantic states, Ohio, Kentucky, and the eastern half of the Lake region. In the Eastern Gulf states and the Atlantic coast states as far north as Virginia the rains of the preceding 24 hours were very heavy, in some localities exceeding an inch and a half. It will be observed also that the winds within the area just outlined blew in the main toward the central area of low pressure, and that the temperatures were markedly higher within the cyclonic area than in the anti-cyclonic area immediately to westward of the storm

area. The isotherms, or lines of equal temperature, bent far northward in advance of the storm center, where easterly to southerly winds prevailed; to the west of the center the cold northwest winds reached far to the south.

High atmospheric pressure prevailed over the area west of the Mississippi River, the highest barometer being over Kansas and Oklahoma. The skies were mostly free from clouds, the winds blew, in general, away from the central region of high pressure, the temperatures were comparatively low, while the isotherms were bent southward, with a maximum dip near the center of the area.

The intimate relationship existing between wind direction and the trend of the isotherms, as explained in preceding pages, is strikingly exhibited in this chart. The difference in temperature between the centers of cyclone and anti-cyclone along the 40th parallel of latitude at 8 a. m. was fully 50°.

The successive changes in weather conditions at Baltimore as these two systems—the cyclone and anti-cyclone—moved eastward are shown in the accompanying diagram. (See Fig. 117.)

The weather conditions over the United States do not always exhibit these cyclonic and anti-cyclonic systems so well defined, but during the winter season their outlines are nearly always easily recognizable. In place of a definite succession of "highs" and "lows" such as are shown by this chart of February 2, 1902, there may be a number of ill-defined and scattered centers of high and low pressure, causing a period of unsettled weather conditions.

COLD WAVES.

When anti-cyclonic waves are accompanied by a fall of 20° or more (exclusive of the diurnal fluctuation) to a stated minimum, within a period of 24 hours, they are technically known as cold waves. Sudden changes in temperature such as are here described are of comparatively frequent occurrence in the northern tier of states, but do not reach as far south as Baltimore in any great numbers. In their progress eastward and southward these cold waves lose much of the severity shown when

they first enter this country from the Canadian Northwest Territory. By the time they reach the Atlantic coast many of them have lost the distinguishing marks of a genuine cold wave. In the official records of the United States Weather Bureau we find that out of a dozen or more anti-cyclones which enter this country every winter in the extreme Northwest as cold waves, but three, on an average, retain sufficient of their severity to be classed as cold waves as they pass over Baltimore.

In some winters Baltimore has been entirely free from them. This was the case in the winters of 1873-4, 1885-6, and 1889-90. Some times as many as six have been experienced in one season, as in the winters of 1881-2, 1884-5, and 1903-4. From 1870 to 1904 the monthly distribution of cold waves[1] in Baltimore has been as follows:

November.	December.	January.	February.	March.	Total.
8	19	23	25	17	92

The Cold Wave of December 13-15, 1901.

The eastward and southward progress of cold waves from the northwest is well exemplified in the weather charts of the United States Weather Bureau for the 13th, 14th, and 15th of December, 1901.

At 8 a. m. of the 13th there were two well defined and extensive areas of high pressure, or anti-cyclones, shown upon the chart: One covered the eastern section of the country, comprising all of the Atlantic coast states, with the maximum barometer over Nova Scotia; the other spread over most of the country west of the Mississippi River, with the center to the north of Montana. Between these two vast anti-cyclones, there was a narrow trough of relatively low pressure, extending from the Upper Lake region to the Gulf of Mexico. In advance of this trough of low pressure, or elongated cyclonic depression, the temperatures rose rapidly under the influence of strong southerly winds. To westward of the trough the cold northwest winds blowing out of the well developed anti-cyclone brought freezing weather far down into the southern states. The western anti-cyclone moved southeastward as a great wave of cold air, closely following the cyclonic depression, causing a very steep gradient

[1] See page 128 for details of cold waves.

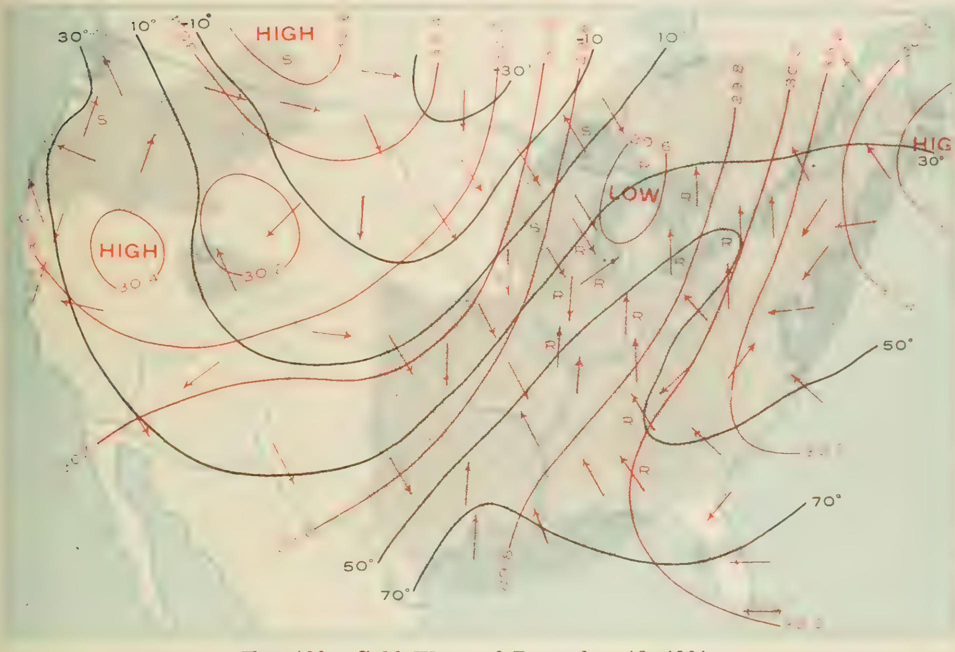

FIG. 139.—Cold Wave of December 13, 1901.

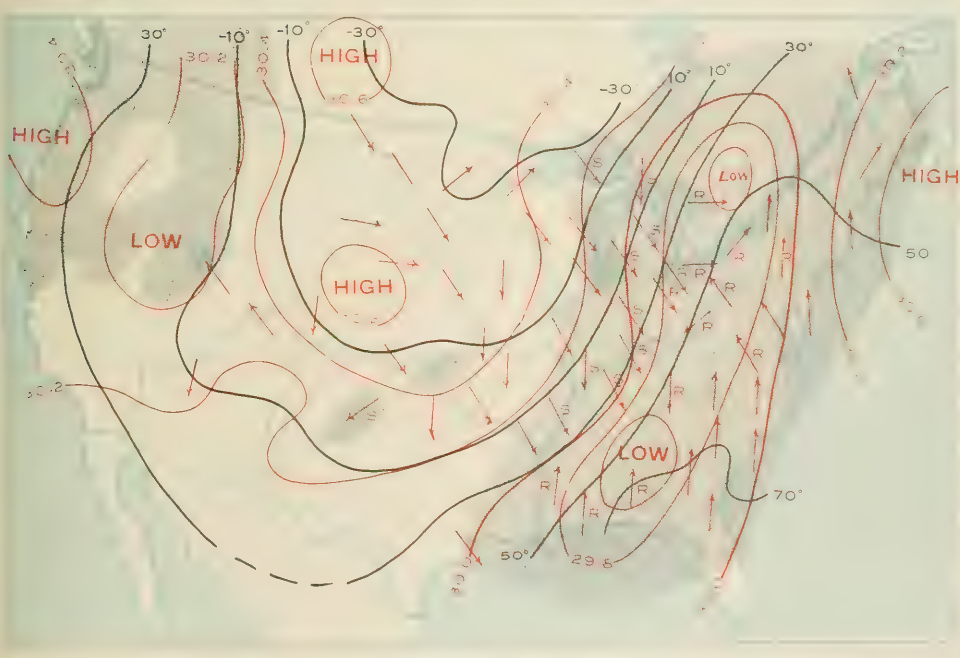

FIG. 140.—Cold Wave of December 14, 1901.

in temperature from west to east along the wave front. In a straight line from Central Alabama northwestward to the Dakotas, from the center of the cyclone to the center of the anti-cyclone, there was a fall of 100° at 8 a. m. of the 14th; Montgomery, Ala., reported a temperature of 70° above zero, and Bismarck, N. Dak., a temperature, at the same hour, of 30° below zero. By 8 a. m. of the following day, the 15th, the isotherm of 20° extended along the West Gulf coast. The cold wave did

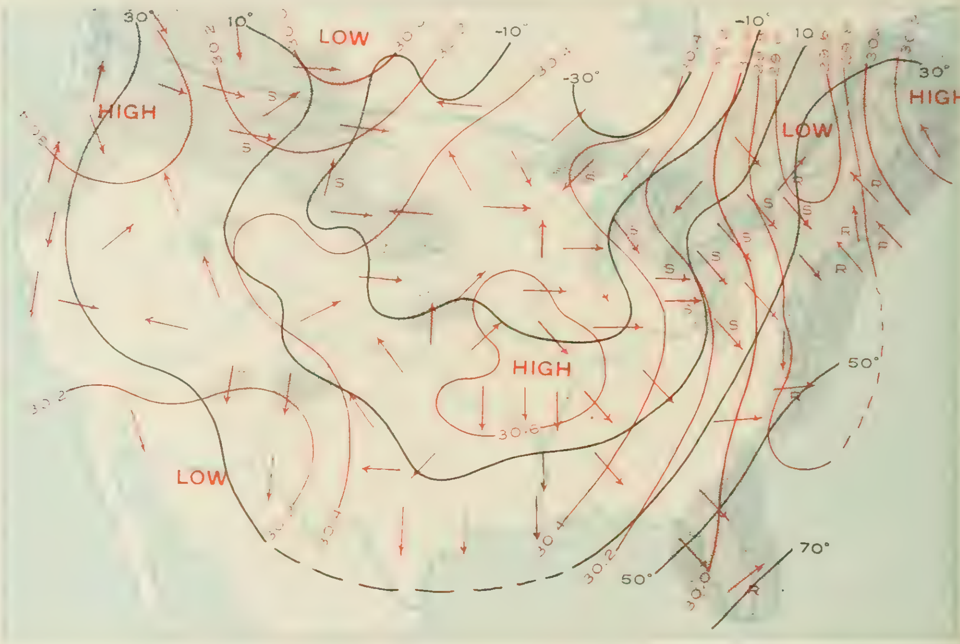

Fig. 141.—Cold Wave of December 15, 1901.

not reach Baltimore until the forenoon of the 15th, and the Atlantic coast on the morning of the 16th.

When the cold wave takes a southeastward path, as it did in this instance, the freezing temperatures very frequently reach the Gulf coast states from 12 to 24 hours in advance of their occurrence in the Middle Atlantic and New England states. (See Figs. 139-141.)

The Cold Wave of February 10-13, 1899.

This, the most intense and wide-spread anti-cyclone experienced in many years in this country, has already been referred to in preceding pages in the discussion of the "Blizzard of February, 1899" with which it was associated. (See Figs. 132 to 138, and Pl. XX.)

Records of minimum temperatures long undisturbed were lowered in many states east of the Rocky Mountains during the eastward and southward progress of this cold wave. It extended even to the West India Islands. At Havana, Cuba, the temperature fell to 54° on the 13th. At Washington, D. C., a minimum of 15° below zero was reported on the 11th. The lowest temperature in the official record at Baltimore was 7° below zero, but temperatures considerably lower were reported from the suburban districts. In passing across the Gulf states zero temperatures were experienced on the 13th as far south as the coast.

Cold waves probably differ from anti-cyclones in general only in the intensity of their development and in the circumstance of being preceded by a cyclonic depression. The conditions most favorable for the development of anti-cyclones are the clear skies and dry quiet atmosphere of the extreme Northwest—conditions which favor rapid terrestial radiation. The general eastward drift of the air in latitudes between 30° and 60° north latitude carries the anti-cyclones, when once formed, along in the general current. With the eastward movement there is a southward tendency of these anti-cyclones, due probably to the centrifugal force of the earth's axial revolution.

These anti-cyclones, like the cyclones, move across the continent at irregular intervals, occupying four to five days in travelling from the Pacific to the Atlantic coast, according to their extent and path. In most cases the center of the anti-cyclone, or high area, passes eastward to the north of Baltimore, but frequently the center passes directly over Maryland, and occasionally to the south. Those passing along the northern route are most likely to bring very low temperatures to our latitudes, but this is not always true. In fact, in the case of the cold wave of December 13th to 15th, 1901, described above, the center passed directly over Baltimore. At such times the temperatures due to the cold

winds from the north or northwest, which accompany all cold waves, are further lowered by the rapid terrestial radiation which takes place in the calm clear centers of the anti-cyclones, especially during the night hours.

The low temperatures associated with cold waves do not as a rule continue more than three or four days. By the fourth or fifth day the normal minimum for the month is again reached. (See pages 117 to 133 for additional details of cold days.)

The Origin of Cold Waves.

The cold waves of the United States have been explained in various ways by those who have studied their history. One hypothesis accounts for them by attributing them to the upper westerly winds which are drawn across the Rocky Mountain range into the cyclonic depressions to the east of the mountains. The clear dry air which descends along the eastern slope cools by radiation into space during the long winter nights to such an extent as to greatly overbalance the warming effect due to compression and insolation as the air descends from the higher to the lower levels.

Another theory attributes them to the southward movement of detached masses of the dry cold atmosphere which form rapidly during the winter months in the region to the west of Hudson's Bay.

A third hypothesis refers them to slowly descending currents of the anti-trades which flow from the equator toward the Arctic region in the higher levels of the atmosphere, the loss of heat during the long journey over the continent being sufficient, by the time they reach the surface in latitudes between 60° and 70°, to account for the low temperatures observed in our cold waves.

These explanations appear plausible, and it may be that the excessively low temperatures observed in our severest cold waves—temperatures of 50° to 60° below zero—must be attributed to a combination of two or all of the causes mentioned.

Recent investigations into the conditions at very great elevations over the equator have shown the existence of low temperatures never experi-

enced at the earth's surface, even within the Arctic Circle. In the summer of 1906 M. Teisserenc de Bort and Mr. Rotch by means of pilot balloons succeeded in obtaining records of a temperature of 122° below zero from an elevation of about nine miles above the earth within the Tropics.

THE COLD WINTER OF 1903-4.

One of the coldest winters on record in the history of Baltimore was that of 1903-4. In some respects it was more severe than the winter of 1855-6, generally regarded as the hardest winter experienced in the Middle Atlantic states. There were very few excessively cold days, the low average temperature for the three winter months being due to long continued moderate cold. The average temperature for the entire season was 6.3° per day below the normal. The winter most nearly approaching this in continued cold was that of 1892-3, with a daily departure of 5.2° below the normal for the season. Next in order comes the famous winter of 1855-6 with an average daily departure of 4.6° below the seasonal average.

With a minimum of 2° above zero on January 5, the winter was not at all remarkable for low temperatures. The trying combination of intense cold, high wind, and snow, occasionally experienced in Baltimore winters, was entirely lacking. The season was characterized by an almost unbroken period of moderately cold weather, and an unusual frequency of snowfall, rather than an excessive quantity. The ice was very heavy; an abundant crop was cut before the first of January, an unusual event for the vicinity of Baltimore. The ice in the Bay and harbor impeded navigation to a greater extent than for many years. For a time during the second decade of January, and again in the middle of February, ice covered the entire Bay from the Susquehanna to the Patuxent, and even the larger steamers were obliged to remain in port.

There was but a single "cold wave" in the technical sense of the term, that is, a fall of 20° within 24 hours to a minimum of 20°, neglecting the usual diurnal variation in temperature; this occurred on the 26th of December with a fall of 22° and a minimum of 11°.

There was less than the average amount of precipitation for the winter season, including snow and rain. The deficiency for the three months aggregated over four inches. The frequency of days with snow was particularly significant. The normal number of snows in the winter season at Baltimore is 12; in 1903-4 there were 22. It is a well recognized fact that a snow cover lowers the temperature materially. Hourly observations of temperature at Baltimore during a period of ten years show that on days when the ground was covered with snow the mean temperature was 10° lower than on the normal winter day. The temperature is lowered during the night by reason of the intense radiation from the snow surface; during the day much of the heat which would otherwise go to warm the atmosphere is employed in melting and vaporizing the snow.

Some of the most significant departures from normal winter conditions are indicated in the following comparison:

THE WINTERS OF 1903-4 AND 1889-90 CONTRASTED.

	Normal Winter.	Cold Winter 1903-4.	Warm Winter 1889-90.
Number of days with a mean temperature below 32°..	34	66	11
Number of days with a mean temperature above 40°..	20	8	63
Number of days with a min. temperature below 32°..	59	78	28
Number of days with a max. temperature below 32°..	14	21	5
Number of days with a temperature of 20° or less....	18	39	6
Number of days with a measurable amount of snow..	12	22	7
Total depth of snowfall in inches....................	24	26	5
Total precipitation (rain and melted snow) in inches.	10	6	7
Number of days with snow on ground...............	22	40	—[1]
First killing frost occurred.........................	Nov. 7	Nov. 7	Nov. 6
Last killing frost occurred..........................	Apr. 4	Apr. 17	Apr. 2

[1] No record.

The following notes on ice conditions during the winter of 1903-4 are taken from the daily journal of the United States Weather Bureau:

1903.
Nov. 7. First ice.
Dec. 16. Ice 4 to 5 inches thick.
1904.
Jan. 4. Ice 6 to 7 inches on Druid Hill Lake. Bay frozen over from Sharp's Island to Ft. Carroll. Ice off Sharp's Island 8 inches thick.

1904.

Jan. 6. Ice on Druid Hill Lake, 8 inches.

Jan. 8. Heavy ice 50 to 60 miles down the Bay. All sailing vessels and small steamers tied up.

Jan. 12. Heavy drift ice in Bay—flows 5 feet thick, making navigation dangerous.

Jan. 13. From Sandy Point up the harbor ice jams delay strongest steamers.

Jan. 18. Ice on Druid Hill Lake, 12 inches.

Jan. 19. Ice fields from Susquehanna to Patuxent. Passable only by means of ice boats.

Jan. 20. Whole Bay solidly frozen over down to Cove Point. Ice 3 to 18 inches. Navigation suspended.

Jan. 29. Fields of heavy drift ice reported as far south as the Potomac. Conditions the worst of the winter.

Jan. 31. Some ice floes have an area of 400 to 500 acres. Navigation hazardous.

Feb. 2. Navigation practically suspended.

Feb. 15. Ice in harbor again becoming a serious obstacle to navigation in spite of the good work of the ice boats.

Feb. 18. Ice conditions nearly as bad as at any time of the season.

Feb. 19. The steamer *Alabama* from Old Point ran into drift ice extending from shore to shore only 30 miles above Old Point.

Feb. 21. The largest steamers are remaining in port on account of ice.

Mar. 2. The ice in the Bay is causing no more serious trouble.

THE WARM WINTER OF 1889-90.

The winter of 1889-90 was quite as remarkable for its mildness as that of 1903-4 was for its severity. The excess in temperature was even greater than the deficiency of the winter in 1903-4, being nearly 8° above normal per day, as compared with 6° below in 1903-4. The winter passed without a single cold wave. The seasonal snowfall (5 inches) was the lightest since 1871, or since the establishment of the local office of the Weather Bureau. The number of days upon which snow fell was but 7 as compared with an average number of 12 and as compared with 22 in 1903-4. There were but six days of the season on which the temperature fell as low as 20°; in 1903-4 there were 39 days with a temperature of 20° or below.

On 12 days of the winter of 1889-90 the temperature rose to points never reached upon those days in 30 years, and upon two days the highest temperature recorded in December and January occurred, namely, 73° on December 26, 1889 and January 13, 1890.

THE DISTRIBUTION OF ATMOSPHERIC PRESSURE DURING THE COLD WINTER OF 1903-4 AND THE WARM WINTER OF 1889-90. (Pl. XXIV.)

The character of the weather of a given locality depends, so far as temperature and winds are concerned, upon the general distribution of the atmospheric pressure over a large area surrounding the locality. The pressure determines the wind direction directly, and the winds, in turn, modify the temperature. If we examine carefully a chart showing the normal winter atmospheric pressure over the North American continent, we find that the barometer is relatively low over Labrador and surrounding regions, and high over the interior of the continent and over the central and southern states. Such a distribution of pressure, as shown in the discussion of cyclones and anti-cyclones in preceding pages, gives to Baltimore and vicinity a prevailing west to northwest wind. If this normal winter distribution of pressure is disturbed, a change in the prevailing wind directions will result, with attendant changes in temperature, and other factors. If we examine the distribution of the mean seasonal pressure over the country during the winter of 1903-4, we find a distribution differing greatly from the normal. The centers of the areas of high pressure during December, January, and February were to the west and northwest of, or over Baltimore, but the areas were much more extensive and intensely developed, causing a steady and strong flow of cold northwest winds during the entire season. A winter season may be severe by reason of a considerable percentage of exceptionally cold days, or by reason of long continued moderate cold. The season of 1903-4 belonged to the latter class. If we examine, on the other hand, the distribution of seasonal pressure during the winter of 1889-90, we find a totally different condition—a wide departure from the normal type. The barometer was persistently high over the southeastern portion of the country—an extension westward of the permanent area of high pressure over the Atlantic Ocean. This distribution of pressure gave to Baltimore and vicinity a prevailing wind direction from the south and southwest during December and January, and an easterly direction during February. As opposed to the prevailing northwest winds of an average winter, these directions all give a relatively high temperature.

In addition, the storm tracks of the winter 1889-90 were, without exception, far to the north of Baltimore, differing widely from the usual distribution, and causing an unusual percentage of southerly winds.

The influence of the mean distribution of atmospheric pressure upon the general character of the weather will be further considered in connection with the discussion of weather conditions in other seasons.

THE VARIABILITY OF WINTER WEATHER.

In the middle latitudes winter is a season of great contrasts. This is particularly characteristic of regions lying near the paths of the storm centers. It is not difficult to find a reason for the great and sudden fluctuations experienced when we bear in mind the conditions described in the preceding pages. In our latitudes there is a continuous succession of atmospheric waves moving from west to east across the continent. Within the troughs of these waves as they move eastward we find, in any well developed type, warm southerly winds which raise the temperature of the localities over which they blow approximately 10° above the normal for the time and place. As the crest passes over the locality it brings with it a cold northwest wind, carrying the temperature an equal amount below the normal. The crests usually follow the troughs within 24 to 36 hours; they may, if they are associated with a rapidly moving storm, follow one another at intervals of 12 hours, or even less.

In the winter season conditions are favorable in the United States for bringing about great fluctuations in temperature in short periods of time. Just to the south we have the tropical regions where temperatures are high throughout the year, and atmospheric moisture abundant. Beyond our northern boundary line are the regions of long winter nights and a clear dry atmosphere, factors favoring a rapid lowering of temperature by radiation. Warm and cold air are alternately brought to the regions midway between these reservoirs of heat and cold, as areas of low and high atmospheric pressure, or cyclones and anti-cyclones, follow one another in rapid succession from west to east across the continent. This material transfer of warm air by southerly winds and cold air by northwest winds is responsible for fluctuations of great magnitude. The

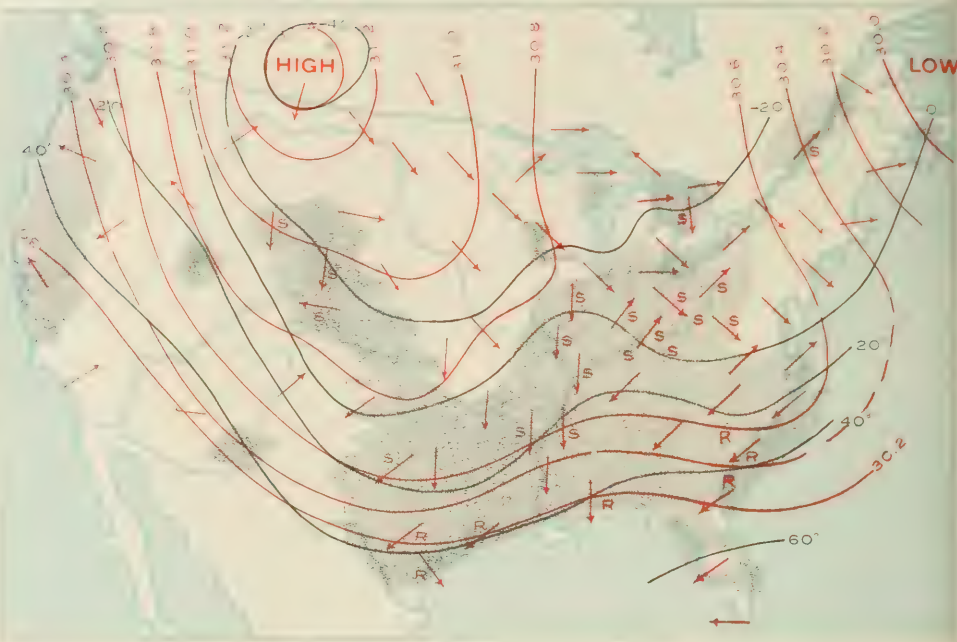

FIG. 142.—Cold February 11, 1899.

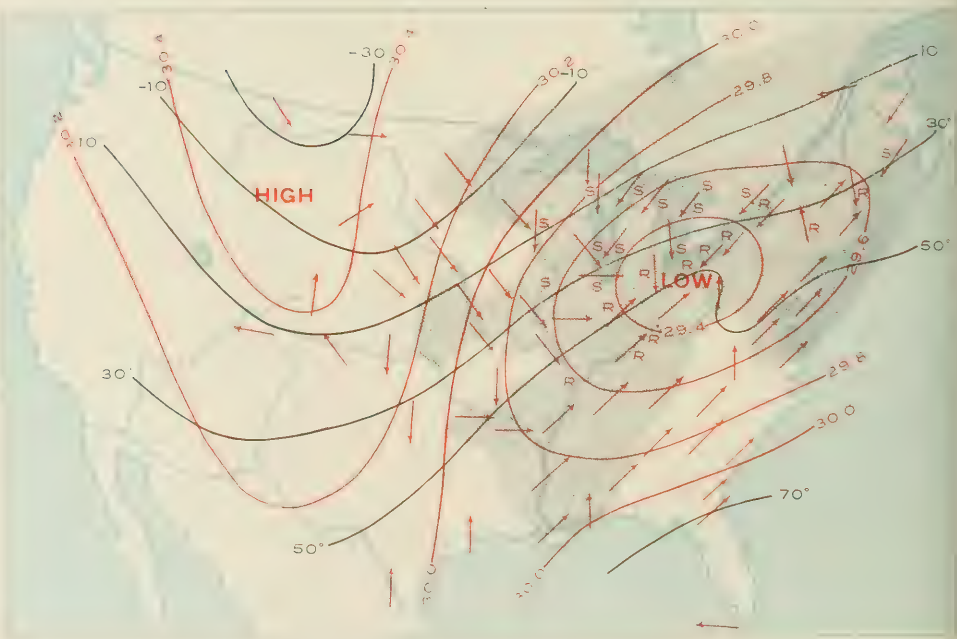

FIG. 143.—Warm February 11, 1887.

contrast is, in all well developed cold waves, intensified by conditions attending all cyclones and anti-cyclones. The warm, moist southerly winds are attended with cloudy skies which cut off rapid terrestrial radiation, thus preventing loss of heat. The cold northwest winds are dry, while the sky is generally clear, permitting rapid loss of heat by terrestrial radiation. These processes, attending all storms, are sufficient to account for the greatest fluctuations observed in terrestrial temperatures, making it entirely unnecessary to call in the aid of extra-terrestrial forces to explain any unusually high or low temperatures observed.

The great fluctuations in temperature experienced in past years in Baltimore are discussed at considerable length in the preceding pages of this report (see especially Plate IV, following page 82); the conditions under which they occurred, however, are not described. Curve D, Plate IV, shows the extreme range of temperature for each day of the year in a period of 30 years. The great ranges are shown to be most frequent in the winter months, although the month of March is not far behind in this respect. February 11 shows the greatest range—on the 11th of February, 1887, a maximum of 72° was recorded in Baltimore; on February 11, 1899, a minimum of 6° below zero, making a total range for the 11th of February of 78°. Even in the month of least variability, August, the difference between the observed maximum and minimum is 31°.

The general weather conditions which prevailed upon the two days of February, showing such great contrasts in temperature are represented in the accompanying charts. (See Figs. 142 and 143.)

On the 11th of February, 1887, a well developed cyclone was passing eastward with its center almost over Baltimore. Warm southerly winds had been blowing over the city for a considerable period, and with some force. By the afternoon of the 11th the temperature had risen to 50°. The depression was followed closely by an anti-cyclone, and on the following days the temperature fell to a minimum of 23° as the center of the anti-cyclone approached.

On the 11th of February, 1899, Baltimore was within one of the most extensive and intense anti-cyclonic areas recorded in local weather

chronology, two days before the great blizzard of this month. The cold northwest winds, aided by the intense terrestial radiation permitted by the clear skies and dry atmosphere, lowered the early morning temperature to 6° below zero, within a degree of the greatest cold recorded in Baltimore in 30 years.

Even more striking are the fluctuations in temperature attending the passage of single storms. On the 24th of February, 1900, Baltimore was within the area of influence of a cyclone, followed closely by an energetic anti-cyclone. By 7 p. m., with strong southerly winds, the temperature rose to 55°. About 8 p. m. the wind suddenly changed to a strong northwest wind and the temperature fell rapidly to 8° by midnight, a fall of 47° in five hours.

HOURLY CHANGES ON FEBRUARY 24, 1900.

		P. M.											Mid-
	Noon.	1	2	3	4	5	6	7	8	9	10	11	night.
Pressure (inches)	29.43	.36	.31	.23	.19	.19	.18	.19	.18	.18	.19	.20	29.21
Temperature (F.)	43	45	46	46	49	51	52	55	37	32	28	18	8
Wind Direction	SE	E	SE	SE	SE	S	SW	SW	NW	W	NW	W	NW
Wind Velocity (miles per hour)	8	8	7	12	8	7	10	12	12	5	8	7	8

On the 31st of December, 1898, as the center of a depression passed over Baltimore and was followed by the advancing front of an anti-cyclone, the temperature fell from 57° at 7 a. m. to 18° at midnight. The usual diurnal rise in temperature to 3 p. m. was totally obliterated. The temperature continued to fall steadily to a minimum of 5° by 8 a. m. of January 2, 1899.

HOURLY TEMPERATURE CHANGES OF DECEMBER 31, 1898.

	A. M.					P. M.											Mid-
	7	8	9	10	11	Noon.	1	2	3	4	5	6	7	8	9	10	11	night.
Temperature (F.)	57	57	55	47	41	38	38	38	37	35	33	31	29	27	25	22	20	18
Wind Direction	SW	SW	NW	NW	N	N	N	N	N	N	N	N	N	N	N	N	N	N

The Weather of Christmas Day (December 25).

In order to illustrate the variability of winter weather in Baltimore, special days have been selected and the general conditions on that day for a long series of years graphically represented upon a single page.

As the popular interest in the weather conditions upon public holidays is always great, one or two days have been selected in each season. For the winter season we have chosen Christmas Day and Washington's Birthday. Charting the weather conditions in this manner the contrasts are more readily perceived than by the use of words and figures.

The factors represented are: The maximum, minimum, and mean temperatures for the day, the mean atmospheric pressure, the average amount of cloudiness during the course of the day, the prevailing wind direction, and the amount of precipitation.

Take for example the weather conditions experienced upon the 25th of December in each year from 1871, the date of establishment of the local office of the United States Weather Bureau in Baltimore, to the year 1906.

The mean temperature for the month of December is 37°; for the 25th of December it is 35.5°. The maximum temperature on the 25th was on two occasions (in 1889 and in 1893) as high as 67°; in 1872 the minimum temperature of the day was 8°, a range of 59°. The fluctuations from year to year are very irregular; sometimes they are abrupt, as the change from 1871 (44°) to 1872 (14°); at other periods they are gradual, as from 1881 to 1884, a slight and steady fall from 40° to 28° in the mean temperature of the day. There were 9 clear days, 13 fair or partly cloudy days, and 14 cloudy days. The winds were prevailingly east to northeast and but once from the south.

The day has been remarkably free from precipitation of measurable quantities, and this has been mostly in the form of rain. In not a single year since 1871 has snow fallen to the depth of one inch upon Christmas Day. Snow has been on the ground to a greater depth but in such instances it fell on the day preceding and remained on the ground. (See Fig. 144.)

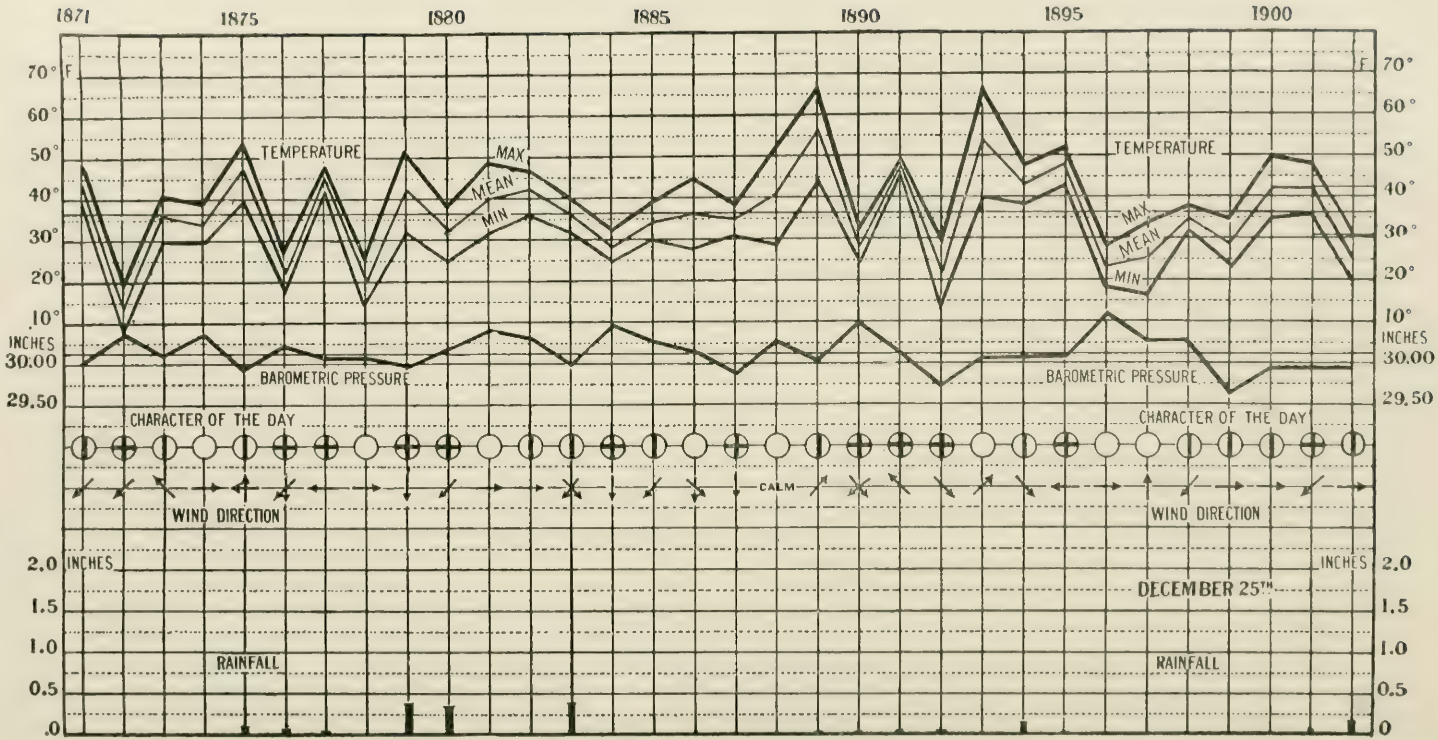

Fig. 144.—The Weather of Christmas Day (December 25).

THE CHARACTER OF THE WEATHER ON CHRISTMAS DAY IN BALTIMORE FROM 1871-1906.

Year.	Max. Temp.	Min. Temp. (Degrees Fahr.)	Mean Temp.	Character of Day.	Wind Direction.	Daily Wind Movement. (Miles)	Precipitation.[1] (Inches)
1871	48	40	44	Pt. cldy	NE	45	...
1872	19	8	14	Cloudy	NE	159	...
1873	41	30	36	Pt. cldy	SE	98	...
1874	39	30	34	Clear	W	245	...
1875	54	40	47	Pt. cldy	E & S	52	0.09
1876	27	18	22	Cloudy	N & NE	85	0.06
1877	47	43	45	Cloudy	E	58	0.03
1878	25	15	20	Clear	W	268	...
1879	52	32	42	Cloudy	N	95	0.38
1880	38	25	32	Cloudy	NE	111	0.35
1881	49	32	40	Clear	W	72	...
1882	47	36	42	Pt. cldy	W	108	...
1883	40	32	36	Pt. cldy	NE & SW	70	0.39
1884	32	25	28	Cloudy	N	191	...
1885	39	30	34	Pt. cldy	NE	144	...
1886	45	28	36	Clear	N & NW	198	...
1887	38	31	35	Cloudy	N	106	...
1888	53	29	41	Clear	Calm	17	...
1889	67	44	56	Pt. cldy	SW	101	0.04
1890	32	25	28	Cloudy	NE & NW	114	...
1891	48	47	48	Cloudy	SE	127	0.02
1892	29	14	22	Cloudy	NW	225	0.02
1893	67	40	54	Clear	SW	116	...
1894	48	38	43	Pt. cldy	NW	171	0.15
1895	52	43	48	Cloudy	E	122	0.01
1896	28	18	23	Clear	W	106	...
1897	34	16	25	Clear	S	62	...
1898	38	32	35	Pt. cldy	NE	76	...
1899	35	23	29	Pt. cldy	W	134	...
1900	50	35	42	Pt. cldy	W	115	...
1901	48	36	42	Cloudy	NE	85	...
1902	32	19	26	Pt. cldy	W	165	0.17
1903	43	34	38	Cloudy	NW	83	0.19
1904	28	23	26	Cloudy	NE	194	0.14
1905	38	26	32	Pt. cldy	NW	162	...
1906	33	13	22	Clear	NW	299	...
Means	42	30	36	Pt. cldy	....	142	0.14

[1] Amounts less than .01 inch not considered.

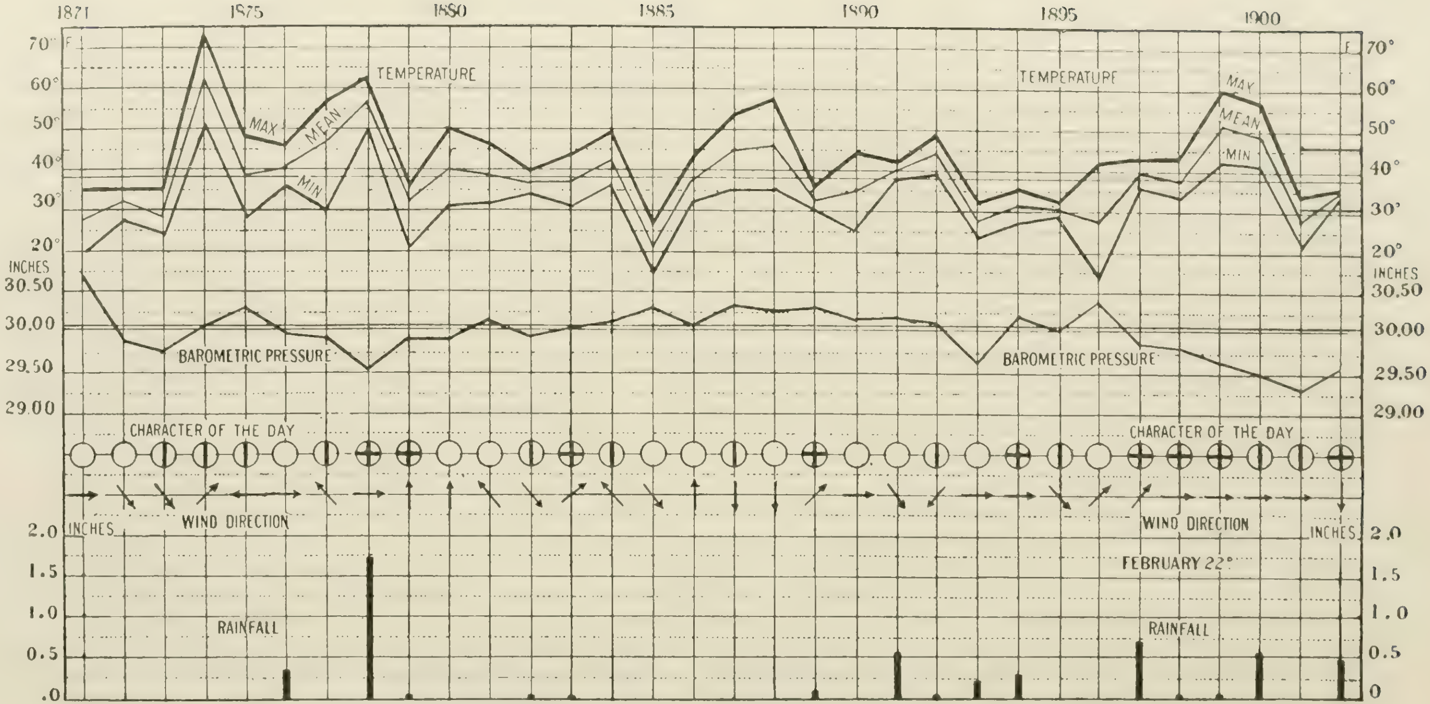

FIG. 145.—The Weather of Washington's Birthday (February 22).

The Weather of Washington's Birthday (February 22).

The weather of the month of February presents more contrasts than that of any other portion of the year. The 22d is no exception; with an average of 38° the temperature was as high as 74° in 1874, and as low as 13° in 1896, a range of 61°. From 1878 there was a steady fall in the mean temperature of the day to the year 1885, though there is apparently no regular period discernible in the annual fluctuation. The grouping of the days with precipitation is somewhat striking. From 1871 to 1890 there were but two occasions upon which rain or snow fell to any considerable depth; namely, in 1876 with a rainfall of three-tenths of an inch, and 1878 with a heavy rainfall measuring over an inch and seven-tenths. Snow fell in 1879, 1882, 1883, and in 1889, but the fall was extremely light in all cases. From 1891 to 1907 rain or snow fell in 1891, 1893, 1894, 1897, 1900, 1901, 1902, and in 1904, though the amounts were small in 1892, 1898, 1899, 1903, and 1907. Fig. 145.

THE WEATHER OF FEBRUARY 22.

Year.	Max. Temp.	Min. Temp. (Degrees Fahr.)	Mean Temp.	Character of Day.	Wind Direction.	Daily Wind Movement. (Miles)	Precipitation. (Inches)
1871	35	20	28	Clear	W	...	...
1872	35	28	32	Clear	NW	170	...
1873	35	24	29	Pt. cldy	NW	199	...
1874	74	51	62	Pt. cldy	SW	173	...
1875	48	29	38	Pt. cldy	E	97	...
1876	46	36	41	Clear	W	166	0.34
1877	57	30	44	Pt. cldy	SE	66	...
1878	63	50	56	Cloudy	W	196	1.71
1879	36	21	28	Cloudy	S	167	0.05
1880	50	31	40	Clear	S	110	...
1881	47	32	40	Clear	SE	143	...
1882	40	34	37	Pt. cldy	NW	279	...
1883	43	31	37	Cloudy	SW	95	0.01
1884	49	36	42	Pt. cldy	SE	90	...
1885	27	14	20	Clear	NW	183	...
1886	43	32	38	Clear	S	168	...
1887	54	35	44	Pt. cldy	N	158	...
1888	56	35	46	Clear	N	74	...
1889	36	30	33	Cloudy	SW	81	0.09
1890	44	25	34	Clear	W	127	...

Year.	Max. Temp.	Min. Temp.	Mean Temp.	Character of Day.	Wind Direction.	Daily Wind Movement.	Precipitation.
	(Degrees Fahr.)					(Miles)	(Inches)
1891	47	38	42	Clear	NW	203	0.54
1892	49	39	44	Pt. cldy	NE	260	...
1893	32	24	28	Clear	W	524	0.21
1894	35	27	31	Clear	W	109	0.32
1895	32	29	30	Pt. cldy	NW	300	...
1896	42	13	28	Clear	SW	180	...
1897	43	36	40	Cloudy	SW	201	0.71
1898	43	34	38	Cloudy	W	111	...
1899	60	42	51	Cloudy	W	122	...
1900	57	41	49	Pt. cldy	W	164	0.54
1901	34	21	28	Pt. cldy	W	120	0.01
1902	36	34	35	Cloudy	N	224	0.40
1903	34	25	30	Clear	NW	227	...
1904	47	34	40	Pt. cldy	NW	240	0.74
1905	39	31	35	Cloudy	NE	240	...
1906	54	39	47	Clear	N	253	...
1907	26	16	21	Clear	NW	249	...
Means	45	31	38	Pt. cldy	....	179	0.44

SPRING WEATHER.

The spring season is a transition period between winter and summer weather conditions. Normally the season has three months, but May is practically a summer month, while March frequently has more of the characteristics of winter than spring. The season, so far as injurious weather conditions are concerned, is very brief. The cyclones and anti-cyclones of early spring belong to the winter type; they are quite as energetic, and follow much the same paths. With the steady approach of the sun the increased heat becomes more apparent, however, and the contrasts in temperature between the winds preceding and following the travelling cyclones become more marked.

One of the first harbingers of spring is the appearance of an area of high atmospheric pressure off the coast of the South Atlantic states. This high area may have advanced from the northwest and, after crossing the continent, settled off the coast, but it is more likely to be an inde-

pendent formation in place, or the westward extension of the permanent area of high pressure normally found over the Atlantic Ocean between the Azores and the South Atlantic states. The presence of an anti-cyclone in the southeast gives to the Middle Atlantic states a steady flow of warm southeast to southwest winds.

March weather is extremely variable. The month has given us some of our severest winter weather, such as the blizzard of 1888, described in preceding pages; it may also be excessively cold and raw, as in 1906. On the other hand, there may be an abundance of fine warm days forcing all vegetable growth four or five weeks in advance of the average season, as in March, 1898.

The explanation for these striking contrasts may be found in the general distribution of atmospheric pressure over the North American continent and adjacent oceans during the early spring season. Under normal conditions in the month of March there is a well developed area of high pressure over the central portion of the continent—the British Northwest Territory; another area of high pressure prevails over the Atlantic Ocean with its axis along the parallel of 30° north latitude, extending westward nearly to the Atlantic coast. These areas are not the same as the travelling anti-cyclones described in the preceding pages. They remain nearly stationary for long periods of time, but are subject to more or less shifting about a central point from time to time. The travelling anti-cyclones are probably detached portions of the larger areas. The character of the weather within these so-called permanent areas of high pressure is the same, however, as is found within the smaller travelling anti-cyclones. Normally, the Middle Atlantic states lie in a belt between these two high areas, and alternately fall within the influence of first one, then the other. One brings us cold weather, the other warm. Occasionally the continental high area will extend to, or move southward and eastward of, its normal limits and bring within its influence the whole of the Middle Atlantic states. Such was the case in the years 1883,[1] 1885, 1888, and 1891. The month of March

[1] *See:* O. L. Fassig. Types of March Weather in the U. S. Amer. Jour. Sci., Nov., 1899.

in these years was decidedly below the normal in temperature throughout the Middle Atlantic states. Again there may be a weak development of the continental high area, in conjunction with a strong development of the Atlantic Ocean high area, or its extension westward beyond its usual limits. The Middle Atlantic states would then be brought within its influence and produce strong southeast to southwest winds or light variable winds and high temperatures. During the month of March in 1878, 1882, 1894, and 1898 the distribution of the monthly mean pressure was such as is indicated, and in all of these months the temperature was well above the normal value. (See Plate XXIV.)

March Winds and Storms.

March is proverbally a windy month. The wind movement for this month is the largest of the year, exceeding even that of the winter months:

AVERAGE DAILY WIND MOVEMENT AT BALTIMORE.

(Average of 30 years.)

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Miles......	142	162	175	166	149	142	134	122	129	137	143	142	145

This comparatively high wind velocity is probably due to the great contrasts in temperature, characteristic of the month. It is the time of the year when the temperature rises most rapidly and the inter-diurnal changes in temperature are greatest:

MEAN DAILY CHANGE IN TEMPERATURE AT BALTIMORE.

(Based on 30 years of observations.)

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Av. daily change±	1.0°	1.0°	1.2°	0.8°	1.0°	0.6°	0.6°	0.4°	0.9°	0.7°	1.0°	0.8° F.

March follows February in the frequency and duration of storm winds:

AVERAGE DURATION AND FREQUENCY OF STORM WINDS AT BALTIMORE.

(Average of 5 years' observations.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Average monthly frequency of winds exceeding 25 miles per hour.	6.2	9.2	7.6	5.0	4.4	2.0	2.6	1.4	2.6	4.2	4.8	4.4
Average duration in hours and minutes.	3.50	4.40	3.40	2.30	1.20	0.12	0.20	3.00	1.25	2.40	2.00	3.00
Longest periods of continuous storm winds (hours).	19	46	23	16	7	0.5	0.5	18	7	9	6	19

EFFECTS OF THE ICE-STORM OF MARCH, 1906 IN THE BLUE RIDGE MOUNTAINS.

ICE STORMS.

While the afternoon temperatures during March are well above the freezing point, the early morning temperatures generally dip below the frost line. Hence the isotherm of 32° is frequently crossed during the passage of the storms of this month. Precipitation, beginning as rain, changes to sleet or snow, or the rain as it falls upon the cold ground or trees and shrubs freezes, covering all exposed objects with a coating of ice. These ice storms are of frequent occurrence in the early spring, but generally occur in March. They frequently cause great damage to property by overloading trees, telegraph lines, etc., and are a source of considerable danger to pedestrians on the city streets. The ice upon trees and telegraph lines sometimes collects in great quantity. Under favorable conditions in the presence of a fog or, in the mountain districts in a driving low cloud, the frozen particles of fog or cloud collect upon the windward side of exposed objects to a thickness of two and even three inches. (See Pls. XXI and XXII.)

THE SQUALL OF MARCH 1, 1907.

A type of storm which occurs with increasing frequency with the advance of spring is shown on the weather map of March 1, 1907. The eastward advance of the storm across the country is marked by the occurrence of severe squalls and thunderstorms, accompanied by heavy rains, within a restricted area of the general storm, or cyclone. The isobars enclosing the storm area form long narrow troughs which are likely to be particularly well marked as the cyclone passes across the Mississippi Valley. Drawing an approximately north and south line through the center of the storm the winds to the east blow from the southeast, while those to the west blow from the northwest. In the vicinity of this line of conflict between the southeast and northwest winds, from the center of the storm southward, we have numerous squalls, thunderstorms, and heavy rains. These local storms occur almost entirely within the southern quadrant of the general cyclone of the type here described. The contrasts in temperature between the southeast winds to the east of the "squall line," as the north-south line above described is sometimes

called, and the northwest winds to the west, are very pronounced; these contrasts are especially well marked in passing from the center of the storm in a northwesterly direction. The map of March 1, 1907, shows a difference of 50° at 8 a. m. between St. Louis, Mo., and Huron, S. Dak., a distance of about 500 miles. The chart also shows the distribution of thunderstorms, occurring within the 12-hour period preceding 8

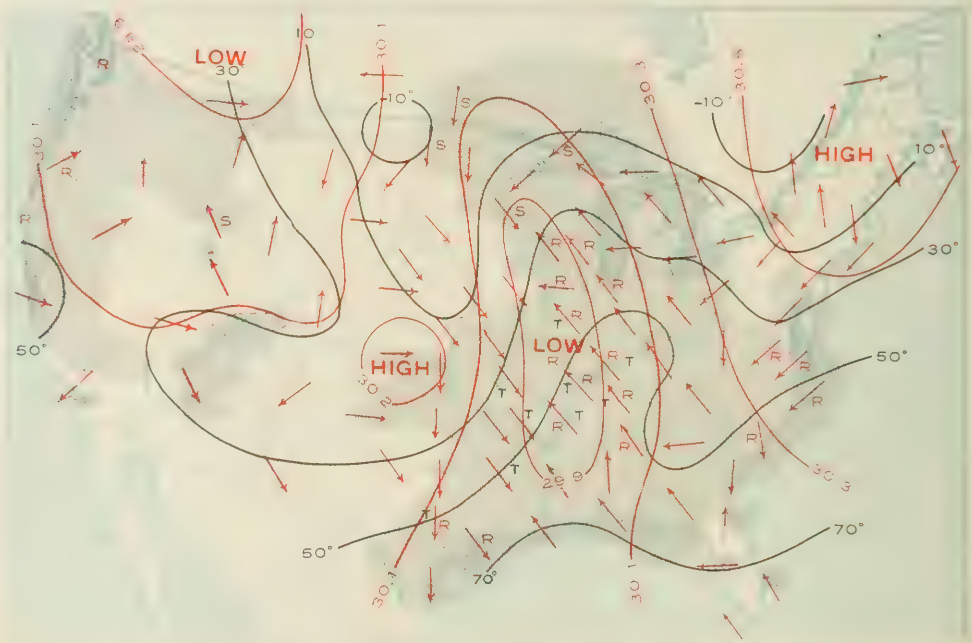

FIG. 146.—The Squall of March 1, 1907.

a. m. of this date. The rains of the Lower Mississippi Valley were heavy, and in some localities, excessive: Mobile, Ala., reported a fall of 6.42 inches in the preceding 24 hours; Montgomery, Ala., 1.32 inches; Anniston, Ala., 1.16 inches; Meridian, Miss., 2.64 inches; Little Rock, Ark., 1.42 inches; and Memphis, Tenn., 1.30 inches. (See Fig. 146.)

Later in the season, with the increasing heat of spring, the most intense variety of local storm—the tornado—is frequently developed within the thunderstorm and squall area of this type of general storm. As the

storm moves farther eastward the squalls and thunderstorms continue to develop, but the tornado becomes of less frequent occurrence, disappearing almost entirely by the time the center of the general storm reaches the coast. In Maryland, for example, a real tornado is of very rare occurrence.

The storm described above changed its shape materially during the succeeding 24 hours, becoming by 8 a. m. of March 2 more circular in form, with its center over the Lower Lake region. In changing to the more common cyclonic type the change in wind direction during the passage of the center of the storm became less abrupt and the squally character of the shift in the wind disappeared to a great extent.

EQUINOCTIAL STORMS.

There is a widespread popular belief in the occurrence of severe storms at the equinoctial periods in March and September. Just why there should be any unusual atmospheric disturbance when the sun "crosses the line" has never been made clear. The belief is an old one, and is especially firmly fixed in the minds of sailors. Like many of the old weather "saws," it will not stand the test of rigid comparison with recorded observations. As a rule, people are not very critical in their definitions of storms, or in verifying the time of their occurrence. In the absence of a severe storm a very mild disturbance will satisfy them. Or if the storm should occur three or four days preceding or following the equinoxial day it is an equinoxial storm ahead of time or a little delayed in its arrival. With such elastic restrictions it is not difficult to realize an equinoctial storm in any month of March. But under these conditions a storm is just as likely to occur upon any other day in the month. If a disturbance be required to show a wind velocity exceeding 25 miles per hour in order to be classed as a storm, there is, according to the Baltimore records, a storm wind every fourth day. If uniformly distributed through the month any day might be selected for a storm and an error of more than two days in time could not be made. Moreover, the records show that the wind velocities on the 21st and 22d of March are not greater than on the days preceding and following. If we con-

sider the occurrence of gales, or winds exceeding 40 miles per hour, we find that during a period of 30 years there were 42, distributed through the year as indicated below:

FREQUENCY OF GALES NEAR BALTIMORE.

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
2	10	3	2	2	3	4	2	0	3	5	6	42

September, the month of the autumnal equinoctial storm, is the only month in the year without a gale to its credit in 30 years, while the month of March has less than the average monthly frequency.

If we regard rainfall as one of the essential features of a storm, statistics are no more favorable to the equinoctial theory than they are in the case of winds. On March 21 the rainfall frequency, based on 31 years of observations, is slightly less than 50 per cent; that is, in 31 years, rain occurred 15 times; on the 22d the percentage of frequency is 40 per cent. On these days rain has occurred less than half the time. Rainfall frequency is somewhat greater on the 19th and 20th, having occurred 16 times in 31 years. (See Table XLIV, page 181.)

When considering amount of rainfall instead of frequency, statistics are even more unfavorable. The average amount of rainfall recorded in Baltimore during 30 years on the 21st of March is 0.21 inch. The amounts for March 19 and 20 are decidedly greater, namely, 0.45 inch and 0.37 inch respectively. The daily average for the entire month is 0.31 inch; hence the amount recorded on the 21st is below the average for the month.

Similar statistics may be shown for the September equinoctial day: On September 21, the average rainfall is 0.16 inch; for the 19th it is 0.93 inch, nearly six times as much; for the 20th it is 0.23 inch; for the 22d, 0.30 inch. The average daily amount for the entire month of September is 0.30 inch. For rainfall frequency in September we have:

September	19..................26	per cent.
"	20..................30	"
"	21..................26	"
"	22..................32	"

The daily average for the entire month is 30 per cent. Rain occurs on the 21st day of March on the average in approximately alternate years; on the 21st day of September every third year. The equinoctial storm, as a destructive storm, or as a storm confined to a single day in the vicinity of Baltimore, is a myth.

Hail Storms.

True hail is of infrequent occurrence in the winter months. While it is often reported in the cold season a careful observer would in nearly every instance report sleet. There is a radical difference between sleet and hail, both in the manner of formation and in physical characteristics. Sleet is an intermediate stage between rain and snow, or a mixture of the two forms, and occurs during the passage of a storm when the temperature crosses the freezing point. Hail, on the other hand, occurs almost entirely during the warm season, when the surface temperatures are far above the freezing point of water.

THE FREQUENCY OF OCCURRENCE OF HAIL IN BALTIMORE.

(Total number in 28 years.)

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
4	3	3	3	11	13	9	6	1	0	1	1	55

It will be noted by the above figures that over half of the hail storms reported in Baltimore in 28 years occurred in the months of May, June, and July. Further details as to frequency and time of occurrence may be found on pages 284-287 of this report.

The most favorable period of hail formation appears to be the latter part of the spring season, and the early summer. The hail storm, like the thunderstorm, is intimately associated with the general cyclone. It occurs in the southern quadrant of the general storm, along the "squall line," described in a preceding paragraph. Hail storms occur almost exclusively in connection with thunderstorms. The reverse of this statement is, however, not true, while but 55 hail storms are recorded in the local annals of the Weather Bureau in a period of 28 years, there is a record of 678 thunderstorms during the same period.

THE HAIL STORM OF MAY 19, 1904.

On May 17 and 18, 1904, a condition of unsettled weather prevailed over the country east of the Mississippi River. Cloudy and rainy weather accompanied the slow eastward movement of a shallow barometric depression from the Middle Mississippi Valley to the Middle and South Atlantic states. On the morning of the 18th the center of depression was over North Carolina. From the morning of the 18th to the morning of the 19th the storm became more limited in area and moved rapidly northward. At 8 a. m. the center was over Lake Huron, with an extension southeastward, forming a secondary depression. There was a well defined line of separation between southeast and westerly winds, extending from the center of the storm southeastward across Central New York, Eastern Pennsylvania, and Southern New Jersey. During the 19th the storm moved slowly eastward, accompanied by severe local storms and heavy rains in the Middle Atlantic and New England states. In Maryland the thunderstorm was accompanied by hail between two and three o'clock in the afternoon. (See Fig. 147.)

The local conditions prevailing at Baltimore during the progress of this storm are shown in detail in the accompanying diagram (Fig. 148).

THE HAIL STORM OF APRIL 27, 1890.

A hail storm of unusual severity passed over the city on the 27th of April, 1890. A detailed account of local changes appears in the daily journal of the office of the Weather Bureau, from which we quote the following:

Dense fog prevailed in the morning, gradually disappearing during the forenoon. The temperature rose rapidly from 48° at 8 a. m. to 71° in the afternoon. Cautionary southeast storm signals were displayed at 10.45 a. m.

The most destructive hail storm on record at Baltimore visited the city this afternoon between 3.45 and 4 o'clock. It came from a point between west and northwest, and travelled in a direction a little south of east.

A half-hour before the arrival of the storm, a dense black cloud-mass, tinged with purple and green, was observed extending from the western horizon across the sky to the northeast, and rapidly approaching. There were at this time two or three subdued peals of thunder, following some vivid flashes of lightning in the west. The front of the bank was in great commotion and, as it approached, appeared to be preceded by a thin misty veil of

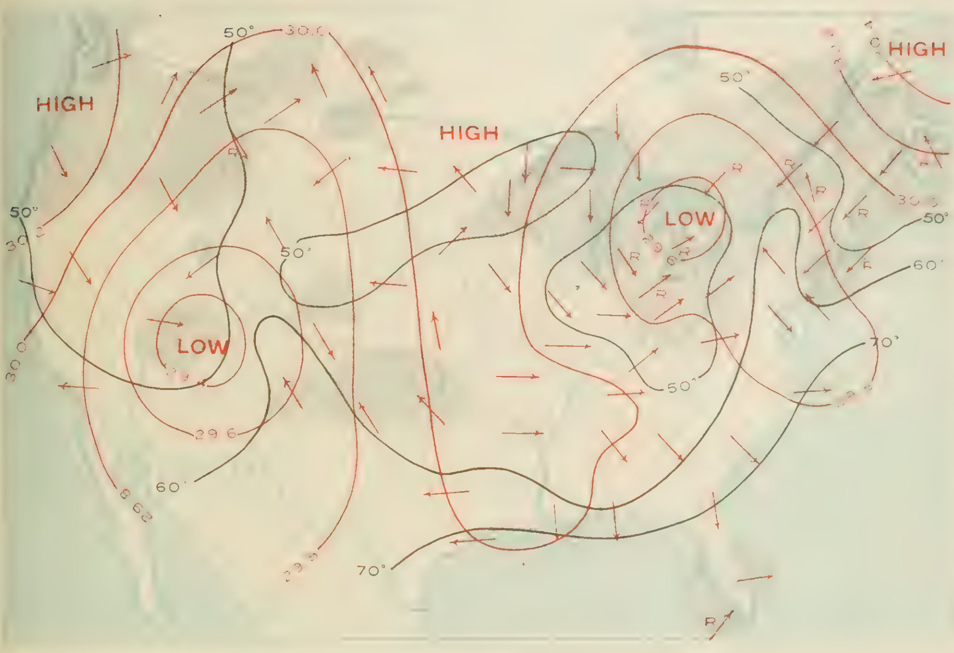

FIG. 147.—The Hail Storm of May 19, 1904.

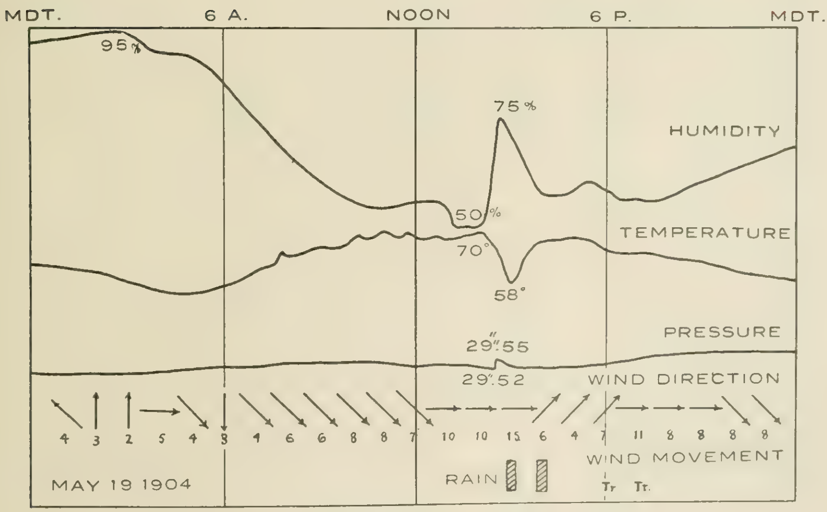

FIG. 148.—The Hail Storm of May 19, 1904.

cloud. There was a sound like the roll of musketry, and the storm burst suddenly upon the city with an almost deafening roar as the great hail stones rained down upon the tin roofs and crashed into the windows, not a building in the path of the storm escaping damage.

Several persons were knocked down by the stones, and many, including a number of children, were cut and bruised. Horses, pelted and cut until the blood streamed from them, could not be controlled, and many ran away, damaging the vehicles and injuring the occupants.

Rain fell in torrents with the hail (0.80 inch falling between 3.45 p. m. and 4 p. m.), poured through the shattered skylights and windows, and flooded houses. The streets were like rivers, and in many places the street-car tracks were covered to a depth of 6 inches by the soil washed down from adjacent hills.

To add to the general disaster the wind blew with great violence, unroofing buildings, breaking in the remains of windows, uprooting trees, and giving the hail stones a dangerous slant to the eastward. For 15 minutes the city was in a state of complete panic, and then the storm passed away almost as quickly as it had come. A half-hour after the storm had left the city, the rain had nearly ceased, the wind was again light, and a rainbow appeared in the east.

The hail stones were as large as hen's eggs. Several measured more than 2 inches in diameter. Three weighed together 12 ounces. Some as large as a man's fist were reported by reliable parties as having fallen in West Baltimore, where the damage by hail was greatest. The hail stones were of various formations. One large stone was covered, on the side unbroken by its fall, with a number of sharp-pointed prisms, and there were many others like it. A large number were oval in form, and these on examination, exhibited a lamellated structure, being composed of alternate layers of transparent and opaque ice, commencing at the center with an opaque nucleus. Others were spheroidal in form and were similar in structure to the oval ones, and like them, very hard. The large prism-covered stones were composed, in the center, of a mass of sponge ice, and were generally crushed upon striking the pavement; no lamellated structure was observed in these.

Although the rain commenced falling at 3.40 p. m. and ended at 5 p. m., it was excessive only between 3.45 p. m. and 4 p. m. when the 0.80 inch referred to above fell.

There was a marked fall in temperature during the progress of the storm. The maximum of the day, 71°, occurred some time before the storm's arrival. Between 3.30 p. m. and 4 p. m. the temperature fell from 67° to 52°, rising again to 60° after the storm had passed.

The wind, which had been very light all day, upon the approach of the storm suddenly veered from the southeast to west-northwest and blew with rapidly increasing force, reaching a velocity of 30 miles per hour at 5 minutes before 4 o'clock. After 4 o'clock it decreased in force and again became light.

From information received from suburban points, it is estimated that the hail band began about 10 miles west-northwest of the city and terminated 5 miles east of the city, and extended in breadth from the southern limits to

5 miles to the north. This would make the band about 25 miles long and about 10 miles broad.

The amount of property destroyed is estimated at from $60,000 to $100,000, the damage for the most part being confined to windows of western exposure—a great many thousands of which were broken—and to skylights and greenhouses. A few windows with a northern exposure were also broken. The damage from the wind was great, a number of houses losing their roofs, while many trees in all parts of the city were blown down. There was no loss of life.

The physical structure of hail stones is well known. There is a central nucleus of opaque snow or ice, consisting of snowflakes and ice crystals mixed with air bubbles. This central nucleus is surrounded by a series of thin alternating layers of clear ice and opaque snowy material. There may be as many as 10 or 12 of these layers. The diameters of the stones vary from a few tenths of an inch to three and even four inches. The variation in the shape of the stones is also very great.

Although the theory of hail formation has received a great deal of attention it is still in a very unsatisfactory state. The explanation of the method of formation of the successive layers of packed snow and clear ice presents great difficulties as we are obliged to rely almost wholly upon speculation as to the physical processes which go on within the heavy cloud mass which constitutes the laboratory of the hail stone. The outward form of the tall "thunder head" identified with hail storms is being carefully studied, and we may hope soon by means of instruments carried aloft by kites and balloons to gather some valuable facts as to the physical processes going on within, which will eventually lead to a better understanding of hail formation.

Spring Frosts.

Marked falls in temperature have a special significance in April and the early part of May in most sections of the Middle Atlantic states. During an average season spring fruits have passed the critical period of injurious frosts by the middle of April in the vicinity of Baltimore, as the average occurrence of the last killing frost falls within the first week of this month. Frequently, however, a killing frost will occur in the latter part of April, and on rare occasions in the first decade of May.

During April light to heavy frosts are generally looked for when a pronounced area of high pressure (an anti-cyclone) passes directly over the Middle Atlantic states from the west or northwest. In addition to the fall in temperature occasioned by the actual transfer of masses of cold air from the northwest or north into the Middle Atlantic states, there is a still further reduction in temperature, owing to the rapid loss of heat

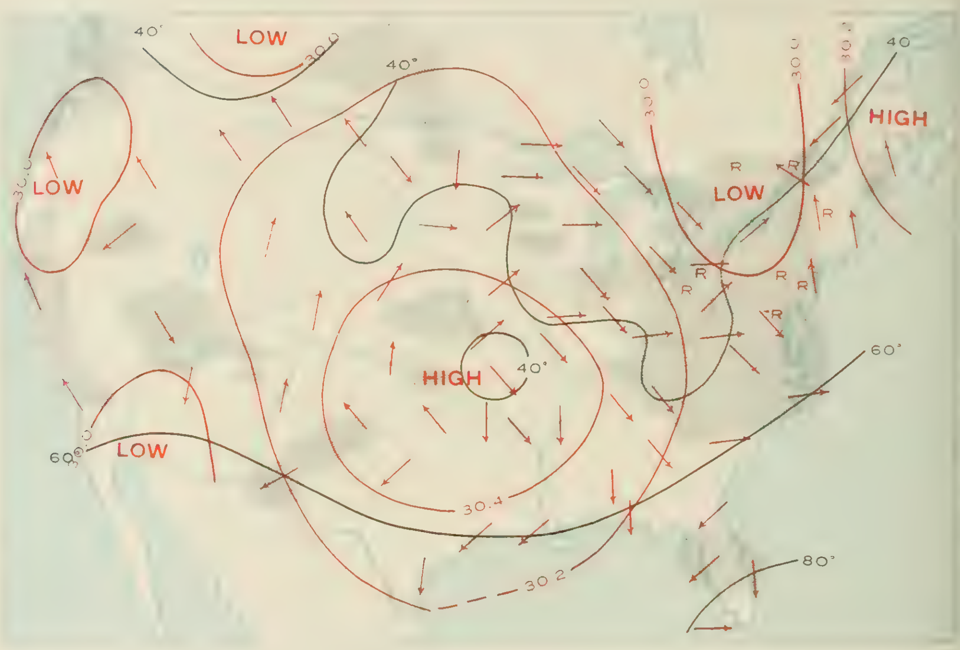

FIG. 149.—The Frost of May 9, 1906.

during the night within the anti-cyclone; the dry air and cloudless skies accompanying these areas facilitating rapid radiation from the ground. When, as frequently happens, the anti-cyclone is preceded by a barometric depression accompanied by rain, the probability of the occurrence of frost is greatly increased, as the atmosphere is then charged with moisture on the approach of the fall in temperature within the anti-cyclonic area. If at the time of the 8 p. m. observation the temperature is between 40° and 50° at Baltimore, and the arrival of a pronounced

anti-cyclone is expected during the following night from the west or northwest, frosts are very likely to occur in the early morning hours. The injury resulting from a frost depends, not only on the fall in temperature, but also upon the state of vegetation, the amount of moisture in the atmosphere, and upon the wind movement. Clear, quiet nights greatly facilitate the production of frost in the lower places, allowing the colder, heavier air to settle near the ground. A clouded sky will prevent rapid radiation from the ground. A moderate wind movement, by thoroughly mixing the air, will prevent any great difference in temperature between the layers near the ground and the air at higher levels. A frost occurring shortly after the appearance of tender plants is likely to do more damage than a heavier frost later on when the plant has become more vigorous.

For details concerning the occurrence of spring frosts see pages 129 to 135.

The general weather conditions on the morning of May 9, 1906, show a situation from which frost may be expected in the Middle Atlantic states during the following night.

Temperatures ranging between 28° and 35° occurred in nearly all counties of Maryland on the 10th and 11th. This anti-cyclone was the occasion of one of the severest spells of cold weather experienced in Maryland so late in the season. All stations in the mountainous portion of the state, and many stations elsewhere, experienced temperatures below freezing. Even the southern portion of the Eastern Shore was not exempt, Salisbury reporting 29° and Princess Anne 31°.

At a number of stations the temperature did not fall below 40°. The minimum in Baltimore was 38° on the 10th. While the frost was quite severe, fruits and vegetables were too far advanced to suffer any very great amount of injury. (See Fig. 149.)

ICE WITHOUT FROST.

The weather map of 8 a. m., April 17, 1905, shows freezing conditions throughout Maryland, but no frosts were reported. A well developed high area with its crest extending from Montana southeastward to Florida was associated with a deep cyclone centered over the Lower St.

Lawrence Valley. Strong, steady west winds prevailed as a result of this distribution of pressure over the Middle Atlantic states. The dry air aided by considerable movement prevented the formation of frost, though ice formed in a number of places. (See Fig. 150.)

Periods of Unsettled Weather.

In the eastward drift of cyclones in our latitudes, the rain area occupies from one to two days in passing a given point. In 76 per cent of all

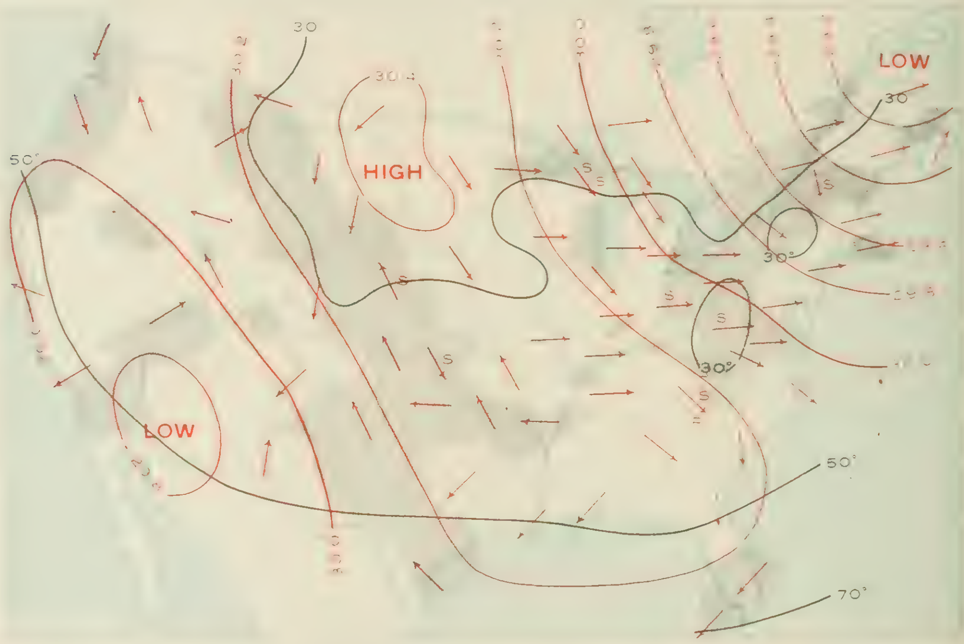

Fig. 150.—Ice without Frost, April 17, 1905.

occurrences of precipitation the rain or snow falls within a forty-eight hour limit in Baltimore. In 13 per cent of instances the precipitation covers all or a portion of three days. This leaves very little margin for extended periods of consecutive days with rain or snow. (See page 213.) Long periods of unsettled weather with rain or snow are of most frequent occurrence in the spring season.

PERIODS OF UNSETTLED WEATHER.

(With 6 or more consecutive days of rain or snow.)

	D.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	Y.
Total frequency in 34 years........	12	11	15	20	14	23	13	12	17	9	7	11	164
Maximum duration (days)..... ...	22	19	17	22	13	23	18	15	19	12	10	10	23
Number of intervening days without rain	6	4	4	2	1	4	3	2	4	0	0	1	4
Seasonal frequency		38			57			42			27		164

These periods of unsettled weather may be due to a great variety of causes. There is not a regular and periodic succession of well developed cyclones and anti-cyclones, such as have been described in preceding pages. The well developed types have been selected for illustrative purposes, as they are simple in outline and more readily interpreted. In studying the actual weather map from day to day we find there are no two weather conditions exactly alike; there is an infinite variety in the outline of isobars, the trend of isotherms, the shape of rain areas, etc. An unusual succession of rainy days may be due to the very slow movement of a cyclonic area, to a rapid succession of storms, to a recurving of the storm upon its path, or to a combination of these causes. It may also be due to the persistence of a so-called "flat map," a map without well defined cyclones or anti-cyclones.

THE RAINY PERIOD OF APRIL 19-25, 1901.

On the morning of April 16, 1901, a depression entered the United States in the extreme Southwest; at 8 a. m. its center was over Arizona. This depression travelled slowly eastward, causing moderate to heavy rains over Texas and the West Gulf states during the 17th and 18th. By the morning of the 18th the center was over Alabama. In connection with another depression centered over Ohio a long trough of low pressure was formed extending from the Lower Lake region to the Gulf of Mexico. By the morning of the 19th the two depressions had merged into a single storm with its center over Georgia. Under the influence of these two storm centers, aided by an area of high pressure in the extreme Northeast, east to northeast winds set in at Baltimore, and rain began to fall on the 19th. The storm turned sharply up the coast on the 19th, accompanied by a very heavy rainfall. At 8 a. m. of the 20th the center was

over North Carolina and Southern Virginia. From the morning of the 20th to the evening of the 21st the storm center had travelled only from Southern Virginia to Western Maryland. On the morning of the 22d the center was found over the Ohio Valley, having been deflected westward—a rare occurrence. The winds at Baltimore continued to blow from an easterly direction. This depression began to fill up and two secondary centers of low pressure developed along the coast, one over Eastern Maryland and the other over the South Atlantic states. By the morning of the 24th these two secondary depressions had merged into a single storm center off the coast of Delaware and New Jersey. This storm moved slowly northeastward just off the coast, disappearing by the morning of the 26th.

This very slow movement and peculiar path of the original storm, and the subsequent formation and sluggish progress of the secondary depressions in the neighborhood of Maryland kept Baltimore within their rain areas for six successive days. The amounts recorded upon each day of this period were not large, but the six days' total exceeded two inches.

DAILY RAINFALL APRIL 19 TO 25, 1901.

April 19, 1901	0.06	inch.
" 20, "	0.56	"
" 21, "	0.54	"
" 22, "	Trace	
" 23, "	0.11	"
" 24, "	0.71	"
" 25, "	0.05	"
Total	2.03	inches.

The rainfall period lasted 162 hours, but the precipitation was not continuous, scattered showers occurring on the 21st, 22d, 23d, and 25th.

THE RAINY PERIOD OF MAY 16-26, 1894.

There is a general impression that rainy periods of much greater length than that recorded above are of frequent occurrence; a close inspection of records, however, will reveal the fact that there are intervening days without a trace of rain.

One of the longest periods noted in the Baltimore records of unsettled weather with daily rainfall was that of the 16th to the 26th of May, 1894.

This period was connected with the passage of a Lake storm of great extent and energy. Here again the path of the storm after leaving the Lake region was peculiar, while the progress was very slow—in fact the center was nearly stationary in the vicinity of Maryland for the greater part of three days. The storm had its origin over the Northern Rocky Mountain slope on the 15th. It moved slowly to the Lower Lake region until the 18th, then dipped abruptly southward and remained over Virginia, Maryland, and West Virginia until the depression gradually filled up on the 21st. In the meantime a second depression developed over Georgia and North Carolina and moved slowly up the coast, disappearing off the coast of New England on the 26th. From the 16th to the 26th Baltimore was within the rain areas of these two storms and much of the time very near their centers.

The rainfall recorded during this period was as follows:

DAILY RAINFALL AT BALTIMORE FROM MAY 16-26, 1894.

May 16, 1894	0.13 inch	May 22, 1894	0.01 inch
" 17, "	0.16 "	" 23, "	1.34 "
" 18, "	0.51 "	" 24, "	0.16 "
" 19, "	0.09 "	" 25, "	0.05 "
" 20, "	1.07 "	" 26, "	0.14 "
" 21, "	0.19 "	Total	4.45 "

While the entire period covered by the rainfall was a little over 10 days, there were but 63 hours of actual rainfall. (See pages 174 and 219 *et seq.* for frequency and duration of wet spells.)

The most notable instances of a long continued rainfall occurring since hourly records were begun by the United States Weather Bureau in 1893 at Baltimore, was that of April 27 to May 1, 1895. The records show that rain fell for 102 consecutive hours. Though the rain was reduced to a light mist at times, it never entirely ceased during this period. The total amount of rainfall was 3.69 inches. There was no

well defined storm area in the vicinity of Baltimore. The barometer was high over the New England states, and a shallow though ill defined depression covered the Gulf of Mexico; the depression moved slowly northward and eastward some distance off the coast, causing a steady northeast wind at Baltimore—a mild "northeaster."

There is a myth associated with the occurrence of rainfall on St. Swithin's day which seldom fails to receive the attention of the press on the 15th of July:

> "St. Swithin's Day, if ye do rain,
> For forty days it will remain;
> St. Swithin's Day, an ye be fair,
> For forty days 'twill rain nae mair."

The nearest approach to a fulfillment of this prophecy, according to the Baltimore rainfall records of the past 36 years, is a period of 9 consecutive days with rain in the month of July. (See page 213.)

The Variability of Weather in Spring.

As an illustration of the changeableness of weather conditions in the spring of the year, we may present the irregular fluctuations from day to day, or we may show the changes which have taken place upon the same calendar day of each year for a long series of years. As regards the degree of variability in temperature the month of March ranks with the winter months. Throughout the early spring rapid fluctuations and strong contrasts in the conditions of successive days are of common occurrence.

Owing to the general interest in the character of the weather on the 4th of March, at least once in four years, this day is selected as a type of March weather. Whatever reason there may be from a historical point of view in favor of continuing to inaugurate our presidents on the fourth of March there is little to recommend the day in past experience of weather conditions and in the small chances for a favorable day. The day falls within a period of rapid warming up in the northern hemisphere, but the advancing sun has not yet carried the day beyond the realm of freezing weather. The early morning temperatures are nearly always below 32°, while the frequent incursions of cold air from the

north and west bring even the average heat of the day close to the freezing point on most occasions.

Added to the discomforts of a raw cold atmosphere we have the proverbial March winds, not infrequently combined with sleet or rain or snow, or a combination of all of these disagreeable elements.

The probability for a fine day is so small that it is surprising that the efforts to change the date of inauguration to the latter part of the following month have not yet been successful.

THE WEATHER OF MARCH 4.

The condition of the weather on the 4th of March is graphically represented in the accompanying diagram for each year since 1871. It might have added interest to carry the diagram back to an earlier date but the period of 37 years represents practically all the chief combinations likely to have occurred in the longer period. While the conditions charted represent Baltimore weather, the close proximity of Washington makes it improbable that there were at any time any material differences in the weather conditions of the two cities. There is most certainly no difference in the variability of the elements.

The average daily temperature on the 4th of March is not far from the point of frost formation. With the usual daily range the fluctuations will be above and below the frost line. When precipitation takes place it is apt to change from rain to snow or from snow to rain, with the intermediate stage of sleet.

In 1873 the temperature fell to 5° above zero in the early morning of the 4th; on the following 4th of March, 1874, the afternoon temperature registered 68° above. In 1880 the temperature rose as high as 74°. Between these widely separated limits the temperature has kept up a continual see-saw about the middle point of 38°.

In the past 37 years rain, snow, or sleet has fallen on 16 occasions, just 46 per cent of the days. The average amount of precipitation is about half an inch and the average duration about 9 hours. The sky has been overcast 10 times, partly clouded 15 times, and clear 11 times. The prevailing winds have been from the west and northwest.

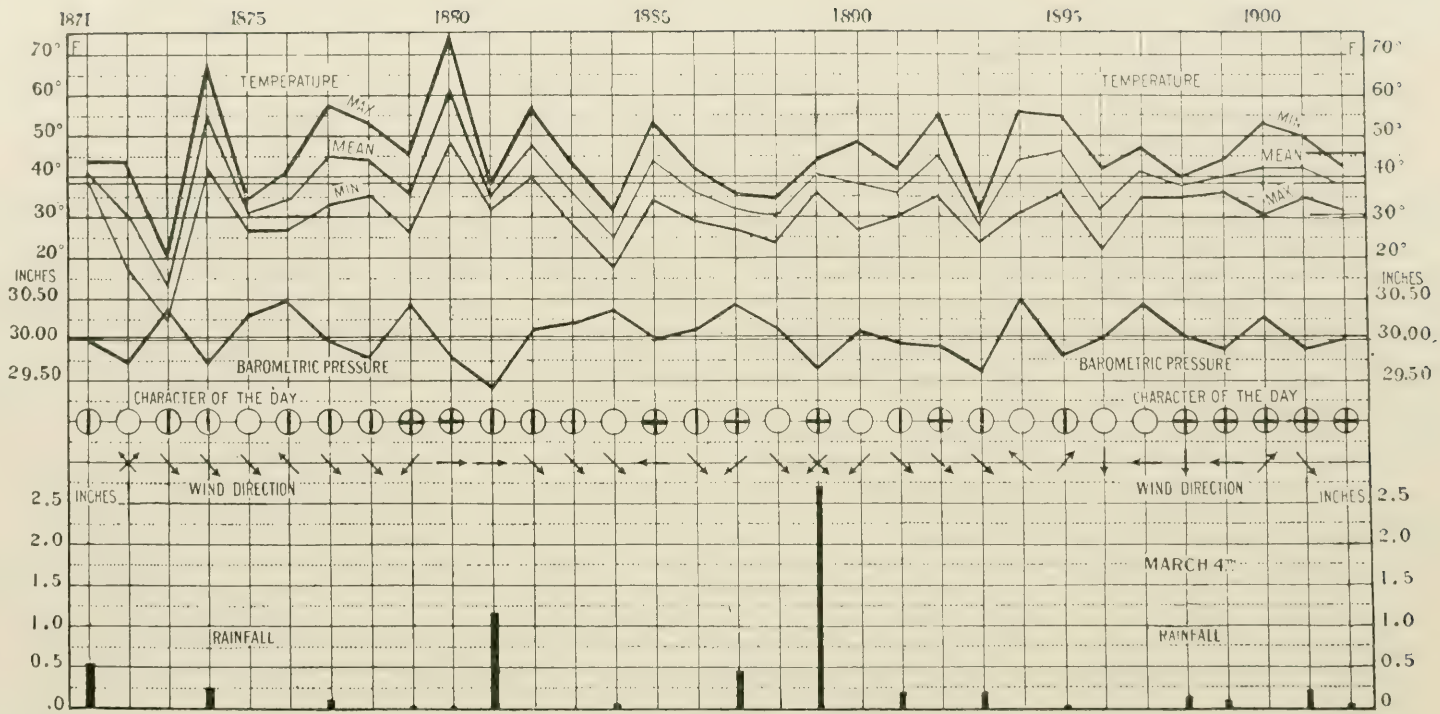

Fig. 151.—The Weather of March 4.

THE WEATHER OF MARCH 4.

Year.	Max. Temp.	Min. Temp.	Mean Temp.	Character of Day.	Wind Direction.	Daily Wind Movement.	Precipitation.
	(Degrees Fahr.)					(Miles)	(Inches)
1871	44	39	41	Pt. cldy	N	...	0.51
1872	44	18	31	Clear	SW & NW	106	...
1873	21	5	13	Pt. cldy	NW	362	...
1874	68	42	55	Pt. cldy	NW	188	0.21
1875	35	27	31	Clear	NW	197	...
1876	42	27	34	Pt. cldy	SE	138	...
1877	57	33	45	Pt. cldy	NW	137	0.09
1878	53	35	44	Pt. cldy	NW	206	...
1879	45	26	36	Cloudy	NE	76	0.02
1880	74	48	62	Pt. cldy	W	223	0.01
1881	38	32	35	Pt. cldy	W	331	1.13
1882	57	40	48	Clear	NW	141	...
1883	43	28	36	Pt. cldy	NW	218	...
1884	32	18	25	Clear	NW	214	...
1885	53	24	44	Cloudy	E	95	...
1886	42	29	36	Pt. cldy	NW	236	...
1887	36	27	32	Cloudy	NE	117	0.45
1888	35	24	30	Clear	NW	198	...
1889	44	36	40	Cloudy	NE & NW	309	2.71
1890	48	27	38	Clear	NE	133	...
1891	42	30	36	Pt. cldy	NW	206	0.18
1892	55	35	45	Cloudy	NW	181	...
1893	31	24	28	Pt. cldy	NW	438	0.18
1894	56	31	44	Clear	SE	110	...
1895	55	36	46	Pt. cldy	SW	306	0.02
1896	42	23	32	Clear	N	458	...
1897	47	35	41	Clear	E	117	...
1898	40	35	38	Cloudy	N	205	0.13
1899	44	36	40	Cloudy	E	171	0.07
1900	53	31	42	Cloudy	SW	65	...
1901	50	35	42	Cloudy	NW	128	0.21
1902	43	32	38	Cloudy	W	108	0.03
1903	54	35	44	Pt. cldy	SE	84	...
1904	35	24	30	Clear	NW	244	...
1905	47	27	37	Pt. cldy	N	250	0.01
1906	54	38	46	Pt. cldy	NW	340	...
1907	39	24	32	Clear	NW	185	...
Means	45	31	38	Pt. cldy	....	175	0.53

THE WEATHER OF MAY 1.

The closing days of April and the first days of May are among the pleasantest of the year in many respects. The temperature is well above the frost line—the mean temperature for the first of May is 59°. The early morning temperatures are more constant than in March or April, the minimum averaging about 50°. The maximum has gone as high as 85°, but it has generally been below 70°. The winds are light and largely from a southerly or easterly direction. (See Fig. 152.)

The rainy days are less frequent than earlier in the season; there are few days in the year with a smaller rainfall probability (see Plate IX). The duration of rainfall is about 7 hours as compared with 9 hours in March and 10 to 12 hours in the winter months. The average amount of rainfall is also quite small compared with that of other days.

The chances for fine weather—a moderate temperature and without rain—are better for the 30th of April and the 1st of May than for any period of the year, excepting the first week in September and the middle of October.

The weather conditions on the 4th of March and on the first of May represent with a fair degree of accuracy the conditions of the early and late spring respectively. They represent sharp contrasts—the former showing all the characteristics of our variable winter climate, while the latter resembles closely the more uniform and settled conditions of our summers.

THE WEATHER OF EASTER SUNDAY.

The weather of this day has been prevailingly cloudy to partly cloudy, with a moderate westerly wind. Rain has occurred on 14 of the 37 anniversaries from 1871 to 1907, and was light in amount on all but one occasion. With an average temperature of 52°, the extremes have ranged between 84° in 1887 and 28° in 1874.

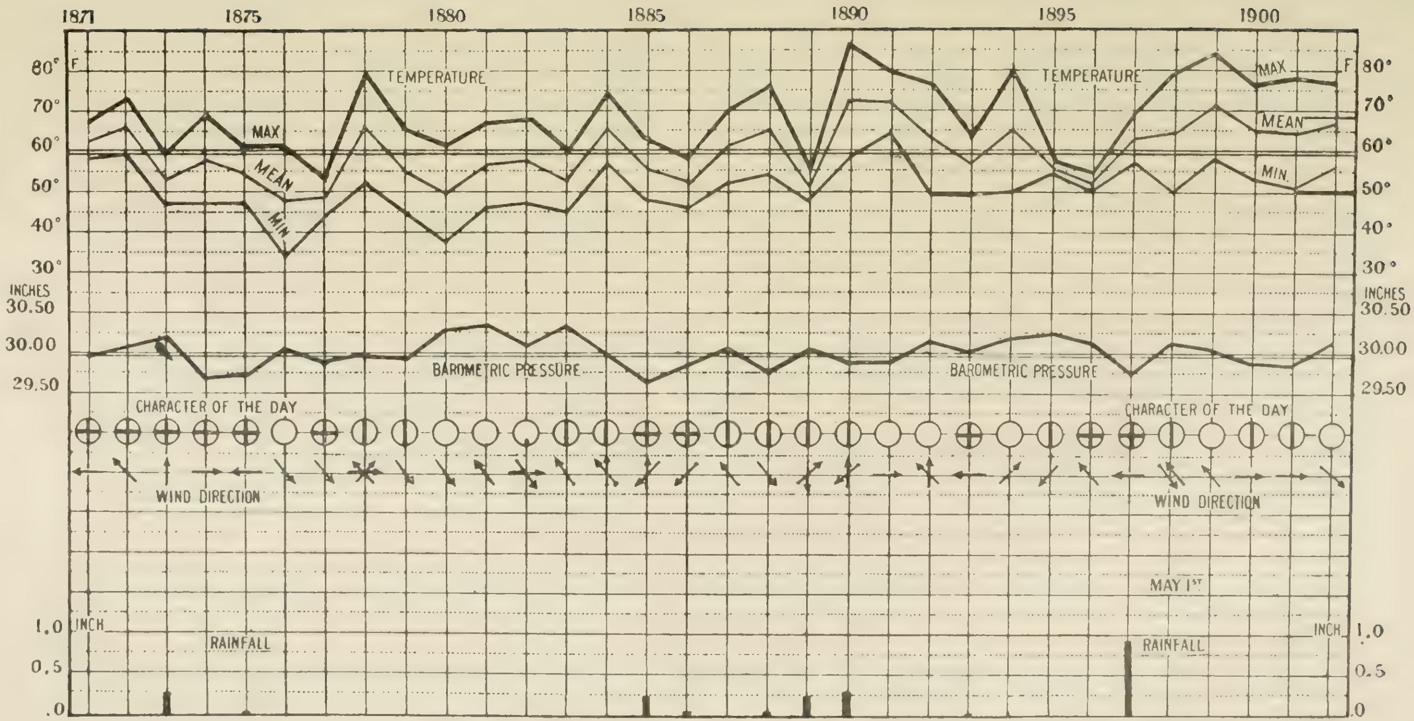

Fig. 152.—The Weather of May 1.

THE WEATHER OF MAY 1.

Year.	Max. Temp.	Min. Temp.	Mean Temp.	Character of Day.	Wind Direction.	Daily Wind Movement.	Precip- itation.
	(Degrees Fahr.)					(Miles)	(Inches)
1871	67	58	62	Cloudy	E	...	...
1872	73	59	66	Cloudy	SE	175	...
1873	59	47	53	Cloudy	S	127	0.24
1874	70	47	58	Cloudy	W	184	...
1875	61	47	54	Cloudy	E	214	0.01
1876	61	34	48	Clear	NW	324	...
1877	53	44	48	Cloudy	NW	109	...
1878	80	52	66	Pt. cldy	SE-SW-W	82	...
1879	65	45	55	Pt. cldy	NW	249	...
1880	61	38	50	Clear	NW	245	...
1881	67	46	56	Clear	SE	175	...
1882	68	47	58	Clear	W & NW	131	...
1883	60	45	52	Pt. cldy	SE	125	...
1884	74	57	66	Pt. cldy	SE & S	155	...
1885	62	48	55	Cloudy	NE	97	0.23
1886	58	46	52	Cloudy	NE	163	...
1887	70	52	61	Pt. cldy	SE	110	...
1888	76	54	65	Pt. cldy	NW	151	0.04
1889	54	48	51	Pt. cldy	N & SW	100	0.23
1890	87	58	72	Pt. cldy	S & NE	144	0.30
1891	80	64	72	Clear	W	161	...
1892	77	49	63	Clear	SE & S	293	...
1893	64	49	56	Cloudy	E	194	0.02
1894	80	50	65	Clear	SW	124	...
1895	57	54	56	Pt. cldy	NE	353	0.12
1896	54	50	52	Cloudy	SE	225	...
1897	69	57	63	Cloudy	E	287	0.94
1898	79	50	64	Pt. cldy	SE & NW	73	...
1899	84	58	71	Clear	SE	101	...
1900	77	53	65	Pt. cldy	W	81	...
1901	78	51	64	Pt. cldy	E	171	...
1902	77	56	66	Clear	NW	187	...
1903	69	44	56	Clear	NW	306	...
1904	72	49	60	Pt. cldy	NW	136	...
1905	62	48	55	Clear	NW	198	...
1906	75	59	67	Cloudy	N	140	...
1907	63	52	58	Cloudy	N	189	0.04
Means	68	50	59	Pt. cldy	....	174	0.22

THE WEATHER OF EASTER SUNDAYS.

Year.	Date.	Max. Temp.	Min. Temp.	Mean Temp.	Character of Day.	Wind Direction.	Daily Wind Movement.	Precipitation.
		(Degrees Fahr.)					(Miles)	(Inches)
1871	April 9	82	73	78	Pt. cldy	W	...	...
1872	March 31	64	44	54	Cloudy	W	183	0.32
1873	April 13	60	42	51	Pt. cldy	NW	244	0.01
1874	April 5	42	28	35	Cloudy	SE	174	0.10
1875	March 28	54	35	44	Pt. cldy	S	137	...
1876	April 16	65	49	57	Cloudy	SW	212	...
1877	April 1	59	42	50	Cloudy	SE	116	0.02
1878	April 21	79	60	70	Clear	NW	156	...
1879	April 13	58	35	46	Pt. cldy	SE	157	...
1880	March 28	59	38	48	Cloudy	NW	99	0.06
1881	April 17	64	44	54	Pt. cldy	W	227	...
1882	April 9	56	49	53	Cloudy	S	97	0.38
1883	March 25	46	30	38	Cloudy	SE	22	...
1884	April 13	55	47	51	Pt. cldy	SW	89	0.15
1885	April 5	60	35	48	Pt. cldy	SW	241	...
1886	April 25	80	54	67	Pt. cldy	NE	142	0.01
1887	April 10	84	46	65	Clear	NW	102	...
1888	April 1	58	43	50	Pt. cldy	SE	160	...
1889	April 21	80	60	70	Clear	NW	172	...
1890	April 6	62	36	49	Clear	SW	115	...
1891	March 29	50	38	44	Clear	N	201	...
1892	April 17	58	42	50	Pt. cldy	NE	158	...
1893	April 2	62	47	54	Clear	NW	266	...
1894	March 25	45	39	42	Cloudy	N & NW	137	0.01
1895	April 14	59	43	51	Clear	N	178	...
1896	April 5	55	33	44	Clear	NW	209	...
1897	April 18	61	41	51	Pt. cldy	W	103	...
1898	April 10	63	47	55	Pt. cldy	E	86	0.01
1899	April 2	43	31	37	Pt. cldy	W	146	...
1900	April 15	65	40	52	Clear	SW	75	...
1901	April 7	56	46	51	Cloudy	W	154	0.02
1902	March 30	62	45	54	Pt. cldy	W	118	0.24
1903	April 12	55	48	52	Cloudy	E	175	...
1904	April 3	46	33	40	Cloudy	NW	295	...
1905	April 23	64	45	54	Clear	N	172	...
1906	April 15	67	51	59	Cloudy	NW	183	1.07
1907	March 31	56	42	49	Cloudy	N	168	0.03
Means		60	43	52	Pt. cldy	...	157	0.24

SUMMER WEATHER.

As the spring advances, atmospheric movements on a large scale become more sluggish. Well defined cyclones and anti-cyclones are of less frequent occurrence and less intense in their development. This is due, doubtless, to the decreasing contrasts in temperature between north and south, and between the oceans and the continents. Attention has already been called to the relatively great differences in temperature between Florida, for instance, and Montana, in the winter months, compared with the differences in the summer months, an average difference of about 75° in January increasing to 100° at times, as compared with about 30° in July.

With the northward movement of the sun the whole atmosphere of the northern hemisphere rapidly rises in temperature during the day. At the same time the days become longer, and the nights shorter; the loss of heat during the long winter nights over the continental masses becomes steadily less.

With the increasing heat of the summer the mass of the air over the continents becomes specifically lighter than that over the oceans. The general surface circulation of the air between continents and oceans is reversed. In the winter time the general drift at the surface is from continents to oceans, in the summer time from the oceans to the continents. As the winter area of high pressure over the northern-central portion of the North American continent diminishes in strength, the Atlantic high area increases in extent and intensity. With its center usually over the Azores, it extends westward across the Atlantic Ocean to the South Atlantic states in the summer time. With this change in the distribution of atmospheric pressure from winter to summer there is a change in the prevailing wind direction. Maryland, in common with all of the Middle Atlantic states, has a prevailing west to northwest wind in the winter months, the air blowing out of the continental high area; in the summer months the prevailing direction is southeast or southwest, coming from the Atlantic high area to the southeast of the Middle Atlantic states.

In the summer season the paths of the centers of cyclones are confined mostly to the northern tier of states, the Lake region and the St. Lawrence Valley. Hence marked cyclonic changes in temperature are infrequent in the states farther south. The distinguishing feature of the temperature changes is the diurnal variation, the difference between the early morning and the afternoon readings of the thermometer. In the winter and early spring months the irregular cyclonic changes are far greater than the diurnal change. This conspicuous prominence of the diurnal fluctuation, which is characteristic of tropical climates, is not confined to temperature; it also appears in the wind direction, the rainfall and in local storm frequency.

The increasing magnitude of the diurnal period in the summer months at Baltimore has already been discussed in considerable detail in the first part of the report. Further attention will be directed to characteristic weather types of the summer season in the following pages, especially to conditions which give rise to local storms, such as thunderstorms, squalls, tornadoes, and to hot spells.

Summer Storms.

A glance at Fig. 77 and Fig. 78, on page 277, will at once reveal the existence of an intimate connection between high temperatures and the occurrence of thunderstorms. In our latitudes these turbulent atmospheric disturbances become more and more frequent with the northward movement of the sun, increasing steadily from December to July, and then rapidly decreasing to December. The following figures show the annual average frequency for the vicinity of Baltimore:

THUNDERSTORMS RECORDED AT BALTIMORE (1876-1904).

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
13	11	20	33	107	156	179	111	43	7	6	2	678

Over 80 per cent of the total annual number of these storms occur during the hot season—May to August—and including September and April, the total frequency for the summer half year amounts to 92 per cent, leaving but 8 per cent for the winter half year. The same intimate connection with change in temperature is shown in the diurnal period of thunderstorm occurrence. (See page 276.)

HOURLY FREQUENCY OF THUNDERSTORMS.

Hours ending	1	2	3	4	5	6	7	8	9	10	11	12	
A. M.	7	1	3	7	0	3	6	6	6	8	9	15	
P. M.	22	46	76	78	61	55	69	38	34	31	16	13	Total 610

More than two-thirds of all thunderstorms recorded at Baltimore in 28 years began during the seven hours from noon to seven p. m. Many of the storms occurring later than 7 p. m. had their origin in the early afternoon hours and were carried eastward several hours before being dissipated.

When the thunderstorm does occur in the cold season it is in connection with a *relatively* warm inflow of air towards the center of a cyclone.

During the summer months many thunderstorms occur in the absence of any well defined general cyclonic depression. During a period of abnormally high temperatures due to bright sunshine and a sluggish wind circulation, the lower layers of the atmosphere are excessively heated, resulting in a marked disturbance in the normal rate of decrease of heat with elevation. A brisk vertical circulation is set up, which, in the presence of a high humidity, results in rapid cooling of the ascending air, and formation of cumulus clouds. As this circulation increases in energy the cloud soon developes into a "thunder head" with its accompaniment of heavy rain, lightning, and thunder. Hence dynamic cooling of warm moist convection currents is the chief cause of thunderstorms of the summer season. When these storms occur in connection with a general cyclone the mass of warm moist air which produces the thunder cloud is mechanically forced upward in addition to rising as a convection current. The thunderstorms occurring in connection with a general cyclone are likely to be of wider extent than those due to convection currents alone, and the cool air following the storm is apt to be more lasting. The fall in temperature following the local heat thunderstorm is usually of brief duration.

THE THUNDERSTORM OF JULY 20, 1902.

On July 20, 1902, a thunderstorm of unusual severity passed over Baltimore. Twelve lives were lost, while several hundred houses were unroofed or otherwise seriously damaged, involving a loss of over $200,000.

The wind attained a velocity seldom equalled in the annals of Baltimore weather.

On the morning of the 20th the weather chart of the United States Weather Bureau showed an area of moderately low pressure over the Lower Lake region, the Middle Atlantic and Southern New England states, with the center of the depression over Lake Erie and Southern Michigan at 8 a. m. Cloudy and rainy weather prevailed over a wide area about the center of the oval depression. A well defined area of high pressure covered the country between the Mississippi River and the Rocky Mountains. By 8 p. m. the barometric depression had moved eastward with its center over Pennsylvania, the isobars meanwhile becoming nearly circular. The weather from the Mississippi River to the Atlantic coast and from the Lake region to the Gulf of Mexico was in an unsettled condition, thunderstorms occurring during the day at nearly every reporting station of the Weather Bureau in the Middle Atlantic, the South Atlantic and Gulf states, and the Lake region, accompanied in most cases by light rains. The chart for 8 p. m. shows the general weather conditions within an hour or two after the occurrence of many of the local storms in the Middle Atlantic states. (See Fig. 153.)

The progressive changes in the elements as recorded at Baltimore during the day were particularly interesting and instructive. The barometer slowly and steadily fell during the forenoon; the wind blew from the southwest with a velocity of only 4 to 8 miles until 8 a. m., then increased steadily to 15 or 16 miles per hour by 10 a. m. The temperature rose rapidly from a minimum of 72° at 6 a. m. to a maximum of 94° at 1 p. m. The sky was overcast during the night, but there was considerable sunshine from 7 a. m. until 1 p. m., when a sheet of stratus clouds appeared in the west, intensely dark and advancing rapidly towards the zenith. At 1.25 p. m. small torn cumulus clouds passed rapidly southwest to northeast in advance of the cloud of dust. This was followed by a stratus layer which by 1.30 p. m. covered the entire sky. At 1.45 p. m. the stratus clouds, moving southwest to northeast, began to break away. Between the open spaces strato-cumulus clouds were visible above moving from west to east. (See Fig. 154.)

The first peals of thunder were heard at 1.23 p. m., coming from the southwest. The electrical display was brilliant during the height of the storm. The last thunder was heard at 2.25 p. m. Light rain began at 1.27 p. m., changing to a heavy shower at 1.29 p. m.; the rain moved in dense sheets from southwest to northeast. In the meantime the wind was increasing in velocity; at 1 p. m. it registered 17 miles per hour,

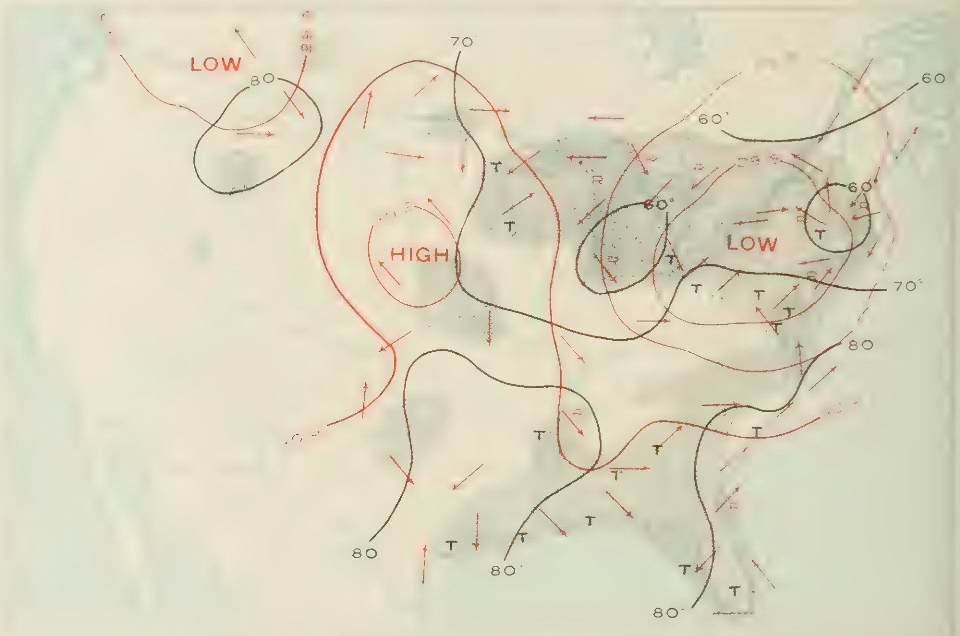

FIG. 153.—The Thunderstorm of July 20, 1902.

remaining at this velocity until 1.20 p. m. In the next five minutes the velocity suddenly increased to 46 miles, and at 1.31 p. m. it blew at the excessive rate of 75 miles per hour from the west. Coincident with the sudden increase in the wind velocity the pressure rose nearly a tenth of an inch in the course of a few minutes, while the temperature fell as rapidly from 94° to 69° and the rain fell in torrents for a few minutes. The wind rapidly fell and by 2 p. m. had regained its early morning velocity of 5 to 6 miles per hour. The pressure regained in half an

hour the height at which it stood before the sudden rise, and then continued to fall slowly until about 8 p. m. The temperature rose rapidly after the sudden fall, recording 84° at 3.30 p. m., maintaining

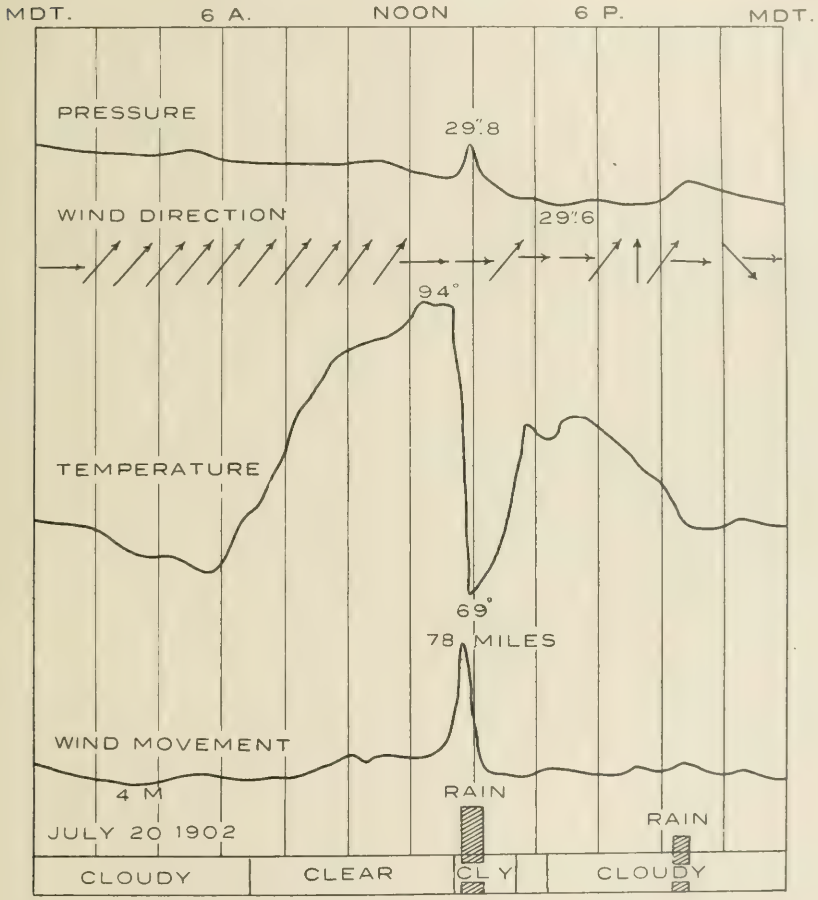

Fig. 154.—The Thunderstorm of July 20, 1902.

this reading approximately until 6 p. m., when it fell rapidly to 76° shortly after 8 p. m.

An hour or so before the sudden fluctuations in wind velocity, temperature, and pressure recorded above, the wind veered from southwest to

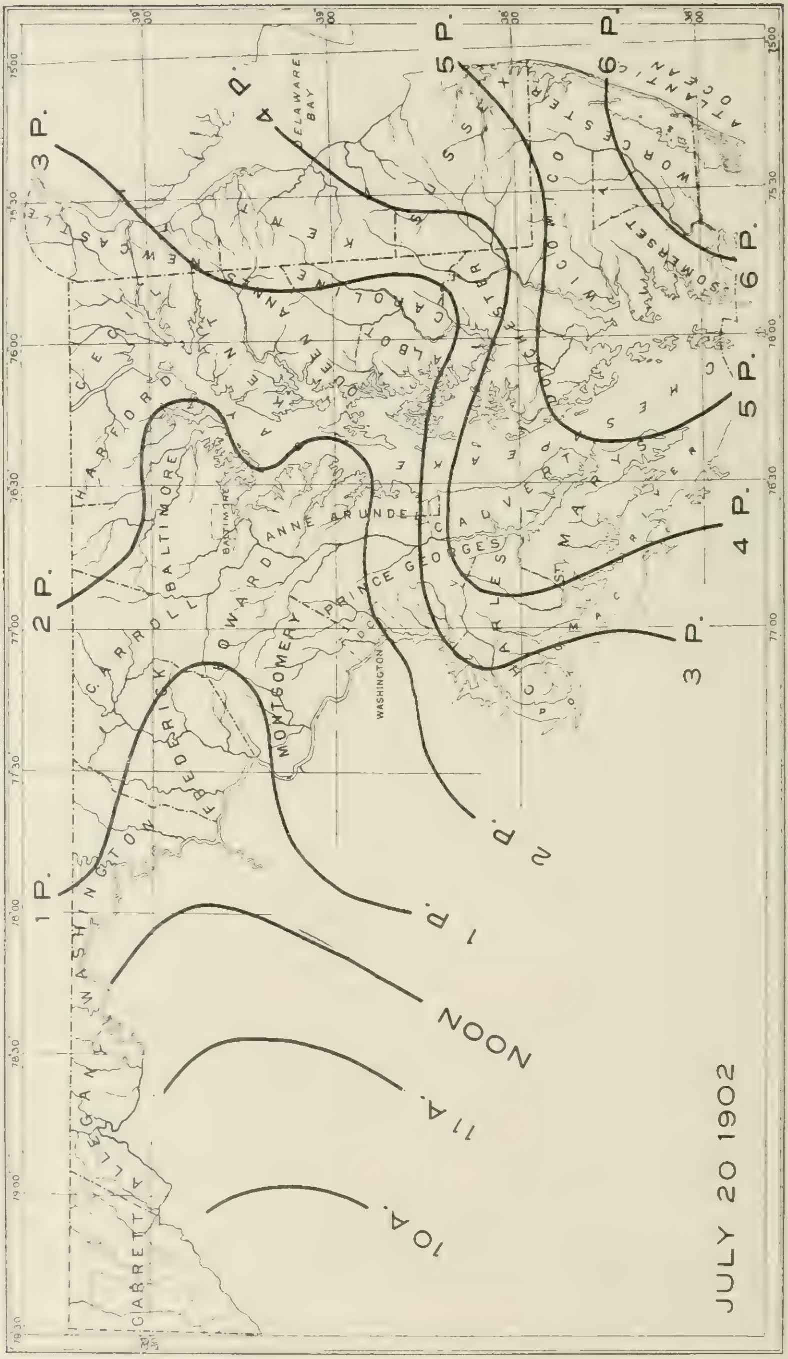

FIG. 155.—Eastward Progress of the Thunderstorm of July 20, 1902.

west. During the afternoon and evening the direction alternated frequently between the west and southwest.

The storm was of short duration; the interval between the first and last thunder heard being about an hour. Its greatest intensity was reached within 20 minutes after the first peal of thunder was heard. The rainfall began at 1.27 p. m. and ended at 1.55 p. m., with a total precipitation of a little over half an inch.

During the morning, cirrus, cirro-stratus, and alto-cumulus clouds were observed passing across the sky from west to east with considerable rapidity. A cloud of dust preceded the thunderstorm, carrying leaves, paper and other light objects high up into the air. Just preceding and during the storm the humidity was fully 40 per cent higher than at the 8 a. m. observation. No portion of the city was free from damage caused by the storm, although north Baltimore seemed to have suffered less severely than other sections.

The storm described above caused considerable damage in all parts of Maryland, though most of the loss of life and property occurred in the vicinity of Baltimore. A special effort was made at the time to trace the path of the storm across the state. Co-operative observers in Maryland, Virginia, West Virginia, and Delaware were requested to report accurately the time of day when the first thunder was heard in their respective localities. Replies were received from about 150 observers, making it possible by charting the recorded times upon a map and joining, by a line, localities over which the storm passed at about the same hour, to follow the storm from West Virginia eastward to the Atlantic coast.

The accompanying chart shows the hourly rate at which the storm travelled. In Central West Virginia the storm began at 10 a. m. From West Virginia it passed into Maryland by way of Washington county between noon and 1 p. m. It then advanced with an irregular wave front eastward to the Chesapeake Bay by 2 p. m. (See Fig. 155.)

The storm front then moved in a southeast direction, passing beyond the limits of Maryland in Worcester County between 6 p. m. and 7 p. m. The total distance traversed by the storm from 10 a. m. to 6 p. m. was about 200 miles, or at the rate of 25 miles per hour. The

irregular form of the storm front and its varying rate of progress across the state are clearly shown in the chart (Fig. 153).

THE THUNDERSTORM OF JULY 3, 1902.

At 8 p. m. of July 3, 1902, a moderate barometric depression was centered over Lake Ontario, while the western edge of an extensive area of high pressure covered the South Atlantic states and extended far out

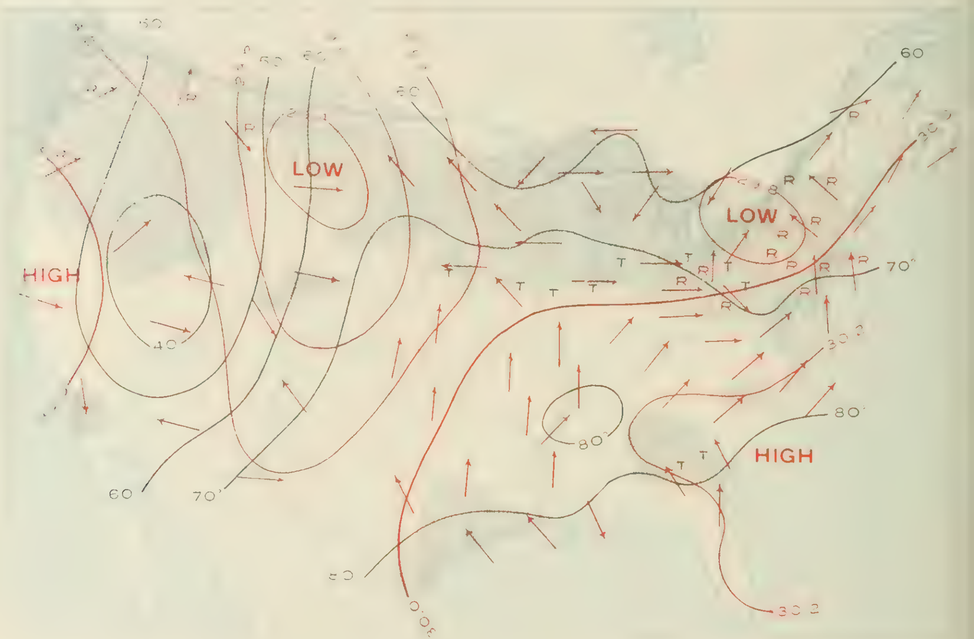

FIG. 156.—The Thunderstorm of July 3, 1902.

over the Atlantic Ocean. The depression was attended by moderate rains in New England, the Lake region, and the Middle Atlantic states.

In the vicinity of Baltimore, as shown by official records, the day was partly cloudy and oppressive; a film of cirro-stratus covered the sky from early morning, through which the sun shone with great intensity. At 4 p. m. stratus clouds were observed moving rapidly from the north and northeast. During the morning and early afternoon a light to fresh

breeze blew from the southwest; at 3.15 p. m. the direction of the wind changed to west, and its force increased to brisk for a brief time. By 4 p. m. the velocity of the wind began to increase rapidly, the clouds

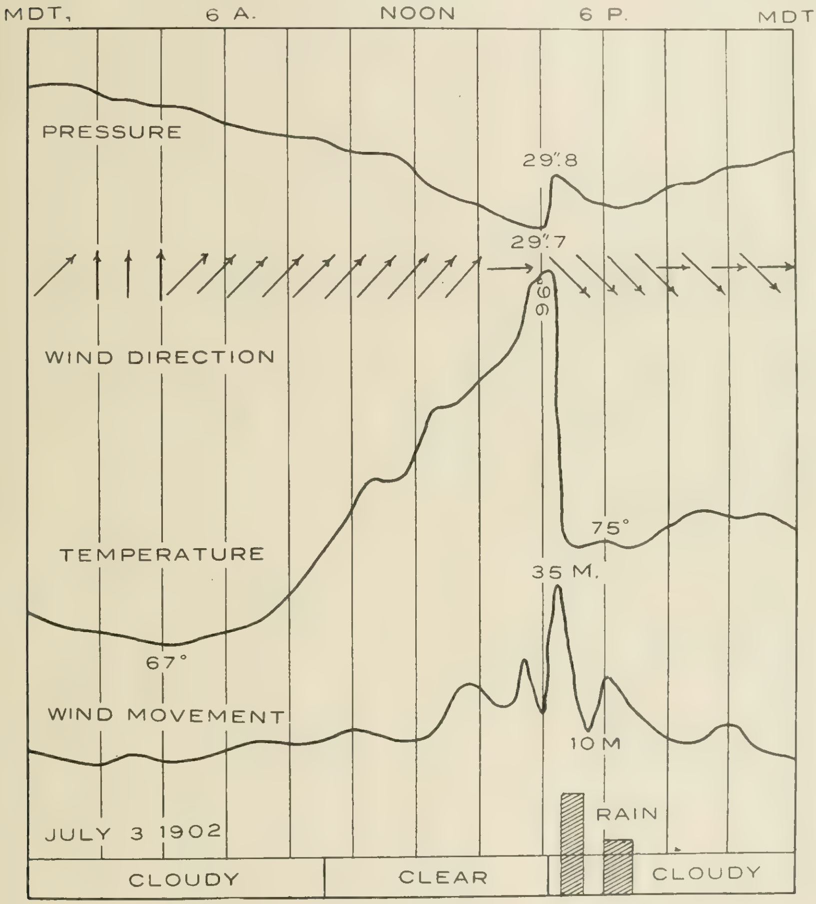

FIG. 157.—The Thunderstorm of July 3, 1902.

maintaining their original direction. At 4.25 p. m. the wind shifted to the northwest, blowing with increasing velocity, and attaining a maximum rate of 34 miles per hour at 4.29 p. m. At the same time great numbers of cumulus clouds were rapidly carried across the sky from the

north-northwest. The storm front moved with great rapidity to the southeast, the usual dust cloud marking the advance. The squall-wind carried light objects high into the air. A number of lives were lost during the squall, while considerable property was damaged, and many trees were uprooted.

Rain began at 4.35 p. m. and continued until 4.50 p. m., the amount being 0.04 inch. On the arrival of the stormfront, marked changes in the barometer and thermometer were noted. (See accompanying diagram.)

The barometer fell rapidly throughout the day until shortly after 4 p. m., while the thermometer rose from 66° at 5 a. m. to 96° at 4 p. m. With the sudden change of wind at 4.30 p. m. from southwest to west and northwest, there was an abrupt rise of nearly a tenth of an inch in the barometer. The temperature fell as abruptly from 96° to 74°, while the wind rose from 12 miles to 32 miles per hour. The change was accompanied by a sharp shower of rain of a few minutes' duration.

The barometer lost a part of the sudden rise during the following hour and then continued to rise slowly during the balance of the day. The temperature remained low after the storm. No thunder and lightning were noted in connection with this storm while it passed over Baltimore. Electrical displays were, however, reported from many parts of the state on this day. The progressive changes were all characteristic of a well defined thunderstorm.

THE THUNDERSTORM OF JULY 12, 1904.

There is a type of pressure distribution which invariably gives rise to numerous and severe thunderstorms and squalls. It is represented in the accompanying chart showing the general weather conditions at 8 p. m. of July 12, 1904. It is the V-shaped depression referred to in a preceding paragraph in connection with a discussion of storm types. In this instance the "squall line" is particularly well defined by a long narrow band of thunderstorms and rain at or near 8 p. m., extending from the St. Lawrence Valley southward through New York, New Jersey, Eastern Pennsylvania, Eastern Maryland, Delaware, and along the coast southward to Florida. (See Fig. 158.)

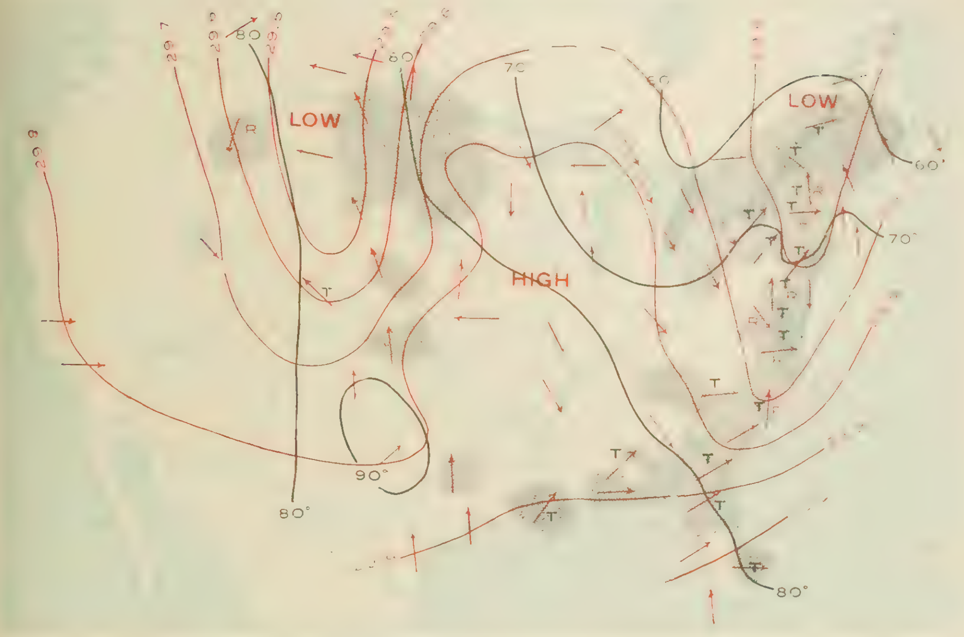

Fig. 158.—The Thunderstorm of July 12, 1904.

THE TORNADO OF JULY 12, 1903.

The Middle Atlantic states are rarely visited by tornadoes. There are descriptions of such storms on record in the annals of Baltimore weather, but the storms were of a mild type of tornado so far as can be judged by local descriptions. Tornadoes occur under general conditions similar to those which give rise to thunderstorms and squalls. They differ, however, from the latter in the character of the atmospheric circulation within the storm, in their greater destructiveness, and in the fact that they are more restricted in the area of their activity. The air within a thunderstorm moves about a horizontal axis, while within a tornado the circulation is about a vertical axis. The thunderstorm moves eastward with the general cyclone with a long wave front many miles in length, the tornado moves along with the general storm in the form of a vertical column of limited extent, generally less than half a mile in diameter,

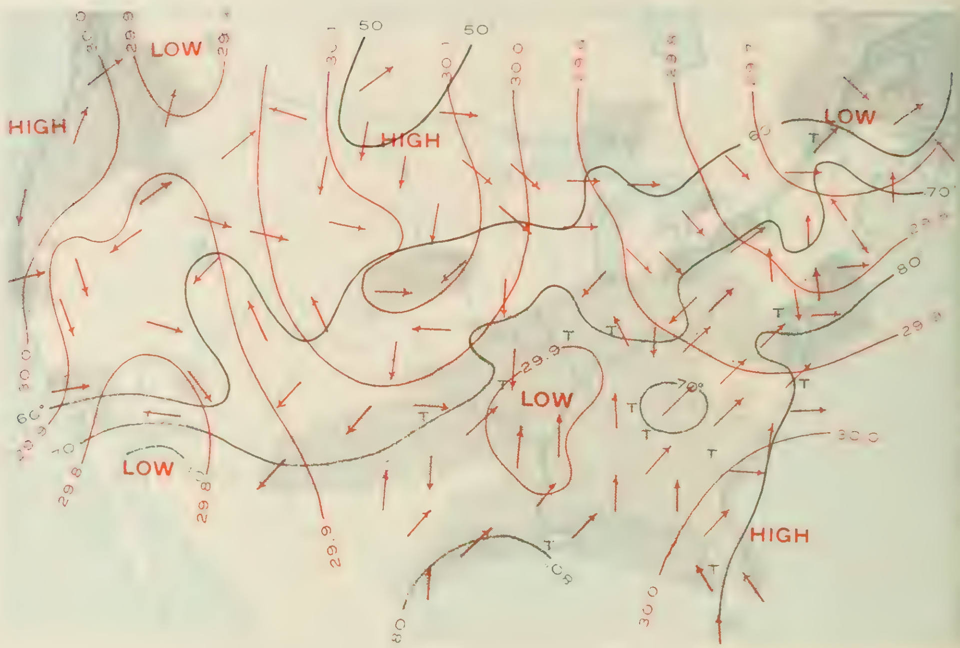

FIG. 159.—The Tornado of July 12, 1903 (8 a. m.).

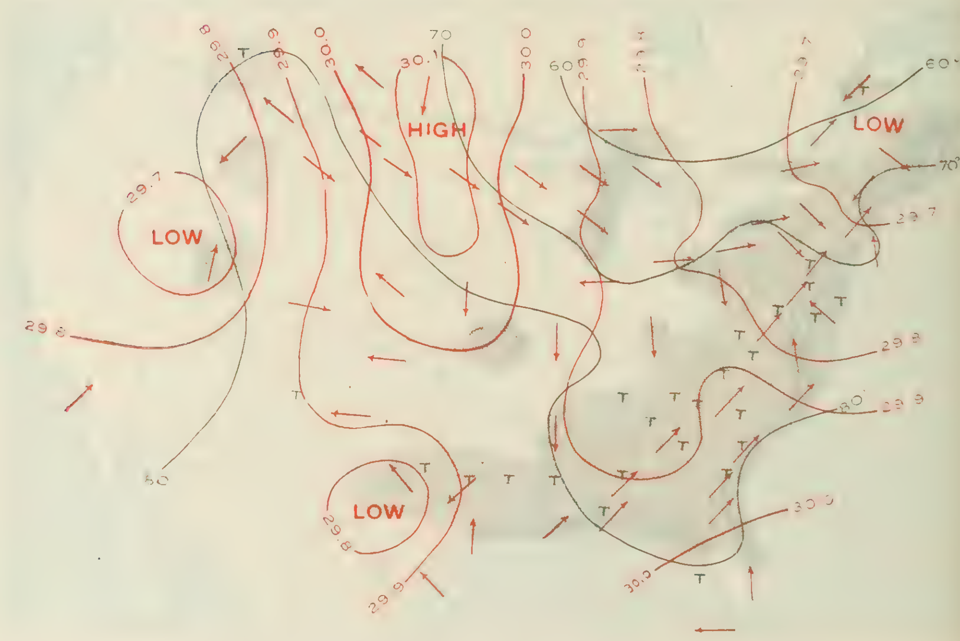

FIG. 160.—The Tornado of July 12, 1903 (8 p. m.).

usually recognizable as a downward extension of the cloud mass which generally reaches to the ground, but sometimes dangles in mid-air like the loose end of a suspended rope.

The storm of July 12, 1903, as it passed over Baltimore, had, from the best information obtainable from eye witnesses, many of the traits of the real tornado, although it is frequently difficult to distinguish between a mild type of tornado and an intensely developed thunderstorm.

The general weather conditions were favorable for the production of local storms over a large portion of the Atlantic and Gulf Coast states and the Ohio Valley. Cloudy and unsettled weather prevailed in the sections named at 8 a. m. of the 12th. Thunderstorms were reported from many stations for the preceding twelve hours. There was an area of high pressure in the northwest, and a barometric depression over the Gulf of St. Lawrence, with a secondary depression forming over the Lower Mississippi Valley. The temperature conditions were nearly normal, but the humidity was high. The prevailing wind direction at stations in the Atlantic Coast states was from the southwest and light in force, excepting in the South Atlantic states, where they were fresh to brisk. During the succeeding 24 hours the secondary depression had developed and moved rapidly northeastward over Maryland, the center being over Massachusetts at 8 a. m. of the 13th, accompanied by heavy rains and severe local storms in the South Atlantic states, and near the coast in the Middle Atlantic and New England states. The following heavy rainfalls were reported for the preceding 24 hours at 8 a. m. of the 13th: Baltimore, Md., 3.98 inches; Washington, D. C., 3.02 inches; Atlantic City, N. J., 1.74 inch. (See Figs. 159 and 160.)

The records of the local office of the United States Weather Bureau contain the following account of the storm as recorded by the official and other observers:

On July 12 thunderstorms and heavy rainfall were general throughout the section. At Baltimore the storm at its height developed destructive features over a limited area. A funnel-shaped cloud, peculiar to the tornado was clearly in evidence a few minutes after noon, and the narrow path pursued by this cloud was also the path of devastation. The cloud moved from west to east, descending to the house-tops at two points within the city, leaving a

wide gap of comparatively slight loss between; it evidently struck the ground again a short distance beyond the city proper, judging from the local damage there, and then disappeared, as far as surface traces were concerned. Reports from parts of Kent County, however, would indicate that the storm crossed the Bay and moved over the Eastern Shore, for in that county a narrow area was visited by destructive winds.

The following is the special report of Mr. James S. Harris, the co-operative observer at Coleman, regarding this visitation: "About 1 p. m. an angry black cloud came suddenly over, causing a darkness as of twilight, accompanied by a cyclone and hail. Wheat in shock and stack was blown about, trees blown down, and houses wrecked." In his use of the word "cyclone" the writer doubtless intended to describe a tornado, a confusion of terms so frequently met with in popular accounts of storms of this class. Baltimore and Coleman seem to have marked the extreme limits of tornado winds, although the thunderstorms were more or less severe at many other points on the same day.

In Baltimore the first area visited embraced much of the 1700 blocks of Fulton Avenue, Mount Street, and Calhoun Street; here a funnel-shaped cloud was distinctly observed by a number of the residents, but no definite account of its manner of formation was obtained beyond this. In the second district, which extended from Eager Street and Broadway eastward for six blocks, with a width varying from two blocks to less than a block, the damage was greater and the information obtained was more explicit. A heavy storm cloud approached from the northwest and another from the southwest; they apparently merged at Eager Street and Broadway, where the destruction abruptly began. The funnel-shaped cloud was seen by many, and a loud roaring sound was followed by almost complete darkness as the storm burst. The upper cloud mass was distinguishable, however, with its narrowing extension downwards, the latter appearing to lag slightly behind the mass above in its movement eastward. The whole travelled with almost incredible velocity, only a few seconds elapsing between the time the cloud descended to the house-tops at Eager Street and Broadway and the time when it rose into the air again six blocks to the eastward.

In both districts the nature of the destruction pointed clearly to the fact that the city had been visited by a tornado. In some of the wrecked houses the walls were blown outward, as though by sudden expansion of confined air within, although fully as many fell inward. In one case the four walls had bulged outward, and the roof lay within, about half-way down to the floor of the second story, while not far off roofs had been lifted high into the air and carried a block and a half away before being deposited in an alley to the rear. In all several hundred houses were unroofed or otherwise badly wrecked. The money loss was estimated at $200,000; happily there was no loss of life, although one man was seriously hurt by falling walls, and numerous narrow escapes from injury were reported.

At the Weather Bureau Office, about a mile and a half away, no damage occurred. The self-registering instruments, while presenting interesting records, do not adequately portray the conditions as they existed at the

centers of severe damage. The rainfall at the station was unusually heavy; 2.87 inches fell in 33 minutes, from 12.04 p. m. to 12.37 p. m. The following maximum falls were tabulated:

Greatest amount	in	5	minutes,	0.80	inch.
" "	"	10	"	1.35	"
" "	"	15	"	1.92	"
" "	"	20	"	2.22	"
" "	"	25	"	2.46	"
" "	"	30	"	2.75	"
" "	"	35	"	2.87	"

Further details of rainfall in connection with this storm are given on pages 212 and 213. The rate of rainfall in the districts of greatest storm loss must have been much heavier. The streets were running streams of water, and cellars were entirely filled within a few minutes.

At the Baltimore station the wind was comparatively high from 12.04 p. m. to 12.15 p. m., and brisk to light thereafter. The maximum velocity was 46 miles per hour at about 12.05 p. m. The wind direction veered through nearly all of the points of the compass during the storm, as shown by the following record:

Noon to 12.05 p. m.	Southwest.
12.05 " 12.15 "	West (mostly).
12.15 " 12.20 "	Northwest.
12.20 " 12.25 "	North.
12.25 " 12.45 "	Northeast.
12.45 " 1.00 "	East (mostly).

There was a sharp fall of about 15° in temperature at the beginning of the storm, but at the office of the Weather Bureau the variation in atmospheric pressure was very slight. The only noteworthy feature of the pressure curve was a small but sudden rise of about 0.05 inch, characteristic of severe thunderstorms accompanied by hail.

The general weather conditions on the day of the storm are recorded as follows in the local office of the United States Weather Bureau:

Cloudy day. Not so warm. Atmosphere very oppressive in forenoon; pleasant afterwards. Maximum, 85° at 11 a. m.; temperature then fell to 70° at noon, rose to 74° at 4 p. m., fell to 69° at 8 p. m., and remained stationary until midnight. Sky partly covered at dawn, became overcast by 9 a. m. with alto-stratus clouds. At 11 a. m. a dark low-lying cloud mass appeared on the northern and western horizons, moving slowly. Shortly before noon, the movement of the cloud mass increased very rapidly, and the sky became covered in a few minutes, continuing so the rest of the day. This movement of the clouds was followed by a terrific thunderstorm, thunder being first heard at 11.48 a. m., continuing all the afternoon at intervals, being last heard at 6.45 p. m., becoming recognizable as a second storm at

about 6 p. m. The first storm moved from west to east, the second passed from south to north. A trace of rain fell in the early morning. The periods of rainfall during the day were as follows:

12 noon to 1.10 p. m.
1.45 p. m. to 2.10 p. m.
2.50 p. m. to 3.20 p. m.
4.45 p. m. to 5.05 p. m.
5.40 p. m. to 7.50 p. m.
9.25 p. m. to 9.40 p. m.

The rainfall was excessive from 12.07 p. m. to 12.42 p. m. (2.87 inches), and heavy from 6.20 p. m. to 6.40 p. m. (0.72 inch); the total amount for the day was 3.90 inches. A light southeast wind before noon shifted suddenly to west at noon with increased force, being brisk to high from 12.02 p. m. until 12.27 p. m., with a maximum velocity, at the station, of 46 miles from the west at 12.07 p. m. The winds were light and variable the rest of the day, mostly from the north.

WATERSPOUTS.

Waterspouts are in their mode of formation and in their external appearance similar to tornadoes. In extent, however, they are much more restricted, while they do not compare with the tornado in destructive power. They are of comparatively infrequent occurrence and it is not often that they are observed at close range by an intelligent observer, hence the following description is of special interest:

Early in April, 1902, Captain Fergus Ferguson of the British S. S. *Hestia* left Baltimore for one of the Cuban ports. On April 4, towards sunset, while off Hatteras, the Captain observed several waterspouts in process of formation at a distance of 300 to 400 yards to windward. The largest of these, and the only one completely formed, seemed to be headed directly for the *Hestia*. The Captain at first attempted to change his course sufficient to avoid running into it, but soon discovered that this could not be done. Giving orders for all on deck to go below, he remained until the spout was close upon his ship, and then hastily sought a place of safety. In a moment he heard a deafening roar which was quickly followed by strong gusts of wind and a sudden shock as the spout struck amidships and passed over the deck towards the stern. The Captain reappeared upon deck in time to see two tarpaulins, which had covered the hatches, and a plank 8 feet long by 10 inches wide, high in the air, while his log line with log attached extended straight up into the air to a distance of about 40 feet. Beyond the loss of the lighter movable objects on deck and a temporary feeling of apprehension no harm was done.

When first seen, the waterspout was incomplete. A portion of the cloud dipped down from the general cloud level of about 2000 feet, while at the same time a column of water was apparently rising from the surface of the ocean just below. At an elevation of between 200 and 300 feet the ascending water column and the descending cloud column met. The diameter of the spout was approximately the width of the *Hestia*, or between 40 and 50 feet. Within the column there was a dark core, almost black, with a diameter of about 2 feet. Captain Ferguson did not clearly recall evidences of a whirling motion, but a strong upward movement is clearly indicated by the facts noted above. No reference was made to any considerable quantity of water being shipped as the waterspout passed over the vessel, a fact which would indicate that the lower portion of the column was composed mostly of spray carried up by the strong wind from the surface of the ocean.

At the time of occurrence of the waterspout the *Hestia* was near the center of a shallow but well defined barometric depression just off the coast of North Carolina. The general storm was moving slowly up the coast. A ridge of high pressure extended from the St. Lawrence Valley southwestward to the West Gulf states. The winds along the coast from New England to North Carolina were northerly.

Summer Hot Spells.

One of the most characteristic features of our summer season is the frequent recurrence of a longer or shorter series of excessively warm days. No summer season is entirely free from them, although at times they are not frequent enough or intense enough to cause comment. These periods vary greatly in length and in the frequency of their occurrence. When the atmosphere is comparatively dry, high temperatures may be endured without great personal discomfort. A high humidity combined with even moderately high temperatures is the cause of most of the unfavorable comment upon the summer weather of the Middle Atlantic coast states.

In the usual course of summer events cyclones and anti-cyclones, though not as frequent as in winter or spring, and not so intense, are yet sufficiently frequent in their passage across the northern portion of the country to maintain a fairly well mixed atmosphere and thus prevent the accumulation of excessively heated air near the surface of the earth. At times, however, we have a comparatively stationary system of cyclones

and anti-cyclones with a small gradient, which may persist with very little change in position for many days. Such a system is of frequent occurrence in the summer season in the United States. An area of high pressure settles over the South Atlantic states, or over the Atlantic Ocean with an extension covering the South Atlantic states, while a barometric depression rests over the Missouri Valley or the eastern slope of the Rocky Mountains. While this distribution of pressure continues there is a steady flow of warm dry southeast to southwest winds over the Middle Atlantic states. If in addition the gradient is small, or the South Atlantic high area moves over the Middle Atlantic states, the winds become very light while the clear skies permit uninterrupted sunshine. The sluggish movement of the atmosphere together with the unobstructed insolation permits the accumulation of excessively heated layers of atmosphere at the surface of the earth. Sometimes these conditions will persist for two or three weeks before the cyclonic and anti-cyclonic systems begin to move eastward in their accumstomed paths and bring about a change.

THE SUMMER OF 1900.

The summer of 1900 was probably the warmest in the annals of Middle Atlantic states weather. The temperatures at the beginning of the season were about normal, June averaging but 0.2° per day below the average of 30 years. Beginning with July the average monthly teperatures remained far above their normal seasonal values until the close of November, the departures from the normal increasing steadily from July to September and then decreasing slowly to November.

July	+2.0°
August	+4.7°
September	+5.1°
October	+4.5°
November	+3.5°

July, 1900. During the first two days in July northerly winds prevailed in Maryland, accompanied by a cool morning temperature of about 60° in the central and eastern portions of the state. On the Allegany plateau the night temperatures were as low as 40°. The maximum after-

noon temperatures were about 85°. On the whole, these days were several degrees cooler than the normal for the season. On the 3d the temperature began to rise rapidly. At Baltimore the maximum was 92°, and, with the exception of four or five days during which the maximum registered in the eighties, the afternoon temperatures remained well above 90° until the 21st of the month. From the 22d to the 31st the maximum readings ranged between 80° and 91°. The hot spell culminated in temperatures of 100° on the 16th and 17th. These temperatures, occurring at Baltimore, fairly represent the conditions that prevailed in the central, eastern, and southern portions of the state. In the valleys of Washington and Allegany counties the figures are somewhat higher. Thus, at Hagerstown, a reading of 105° was recorded on the 16th; at Hancock, 105° on the 15th, 16th, and 17th; at Green Spring Furnace, 106° on the 17th, the highest in the state. Within a very restricted area Maryland offers a great variety of climatic conditions. On the Allegany plateau, in Garrett County, the thermometer did not register above 92° during the entire month, and then only on one or two days.

The temperatures here indicated are all shade temperatures, that is, they were registered by thermometers placed in standard shelters which protect the instruments from the direct rays of the sun, or reflected rays from neighboring objects, but are so constructed as to permit of free circulation of the air. Thermometers exposed to the direct rays of the sun at Chase, in Baltimore County, and at Chewsville, in Washington County, gave an average maximum of 104° on 13 days, with an absolute maximum of 110°. Such temperatures, are, however, not unusual with thermometers so exposed. The average number of days with a maximum temperature of 90° or above in July at Baltimore, based on the 30 years of carefully kept records of the U. S. Weather Bureau, is 9 days. Their frequency has varied from a total absence in 1891, to 18 in 1876. During July, 1900, there were 15 such days at Baltimore, 17 at Washington, 18 at Hagerstown, 19 at Laurel, 21 at Taneytown, and 27 at Hancock. Frostburg had but 5, Grantsville and Deer Park 2 each, while at Sunnyside, Garrett County, there was but one day. The average daily maximum temperature at Baltimore during these 15 days was 95°; the normal

average for the same period is 86°, showing a daily excess of 9°. These excessive temperatures caused the average daily temperatures for the entire month in Maryland and Delaware to be 2.5° to 8° above the normal value for the season.

The weather conditions which usually accompany hot spells were present in a marked degree during July, 1900. The skies were remarkably clear; the winds were prevailingly southwest, and generally light in force; the rainfall was deficient in quantity and frequency. The records from over 50 stations in Maryland, Delaware, and the District of Columbia show an average of 17 clear, 11 partly cloudy, and 3 cloudy days. The average conditions at Baltimore, derived from 30 years of observations, are 10 clear, 13 partly cloudy, and 8 cloudy days. The winds were almost constantly from the south or southwest while the high temperatures prevailed. At Baltimore they were from the southeast, south, or southwest during 20 days out of the 31. The average hourly velocity was but 4.6 miles, approximately the lowest in 25 years, during July, while the highest velocity for the month was only 18 miles, the smallest maximum recorded at Baltimore. Scattered showers fell from the 3d to the 9th; on the 12th and 30th rainfall was general throughout the states of Maryland and Delaware; during the period from the 17th to 26th local showers were frequent. With but few exceptions the total rainfall for the month was decidedly below the average. Baltimore had but 1.31 inch and Washington, D. C., but 1.25 inch, whereas the average rainfall for July in this vicinity is about 4.50 inches. The relative humidity during the period of intense heat was somewhat below the average for the month, a circumstance affording some cause for thankfulness.

While suffering the discomforts of an intense spell of warm weather, we are apt to overestimate its severity as compared with those experienced in the past. Statistics, however, support the assertion that this July hot spell was one of the most trying on record in our vicinity. It is always difficult to make just comparisons in dealing with weather conditions. We feel hot and uncomfortable and look for the cause in high temperatures alone, but do not always find them as high as expected. The element of personal discomfort is due to certain combinations of tempera-

ture, humidity, and air movement, and we have no single set of values to express this element. We can and do measure accurately the temperature, the humidity, and the wind direction and velocity, each separately. Upon these figures we must base our judgment of the severity of any disagreeable period of weather. Since 1871, the date of the establishment of the Weather station at Baltimore, the number of days in July with a maximum temperature of 90° or above has exceeded 15 but twice. In 1878 there were 16 such days with an absolute maximum of 98°; the average of the maximum temperatures was 92.5° as compared with 95° in 1900. The average relative humidity was the same in both instances, namely 63 per cent. The average daily wind movement was greater in 1878 than in 1900, 128 miles in the former and 117 miles in the latter period. In 1876 there were 18 consecutive days with an average maximum of 93°, and an absolute maximum of 99°; the average relative humidity during this period was 63 per cent; while the average wind movement was 125 miles per day. As a result of this comparison with the two most conspicuous rivals for notoriety, we find that the hot spell of July, 1900, was but little shorter in duration; that the humidity was as high; that the average temperature was fully 2° higher; and that the wind velocity, a powerful element of relief on a muggy day, was less.

August, 1900. According to statistics of the Baltimore Health Officer there were 30 deaths during August due directly to sunstroke, and 32 in addition due to excessive heat as a secondary cause. When we come to examine the record of weather conditions during this period, and compare it with the hot spells of the past, we find nothing to equal it in intensity since the establishment of the Weather Bureau Station in Baltimore in 1871.

Baltimore has on an average five days in August with a temperature of 90° or above, with a maximum in the past of 98°. In August, 1900, there were 17 such days, with a maximum of 100°, while this maximum was practically maintained for six consecutive days. Temperatures were even higher, and hot days more frequent at other points in Maryland and Delaware. Thus, in Washington County there were 20 days with a maximum temperature of 90° or above, with an absolute maximum of

103° at Hancock. The highest temperature recorded within the two states was 104° at Millsboro, Delaware, on the 14th.

The hot wave began on the 6th, with a maximum temperature at Baltimore of 97°; from the 7th to the 12th inclusive the afternoon heat reached 99° or 100° each day; from the 13th to the 19th the daily maximum ranged between 90° and 94°. Fortunately the relative humidity was comparatively low, averaging but 65 per cent, the normal value being 70 per cent. A comparatively cool period of four days followed, with heavy showers. The temperature rose again on the 24th to 87°, and ranged between 88° and 96° to the close of the month. While the temperature averaged 6° less daily during the latter period than from the 6th to the 19th, the relative humidity rose from 65 per cent to 81 per cent. To add to the discomfort of heat and humidity, the air movement was extremely light. The total wind movement over Baltimore during the month averaged but 108 miles per day; this is equivalent to an average of 4.5 miles per hour. Such conditions following closely upon the long-continued hot weather of July and the first half of August brought intense suffering to man and beast.

Comparing the hot period of this month with earlier notable hot spells since 1871 we have the following:

	Length of Period.	Average Maximum.
August, 1872	12 days	93°
August, 1888	10 days	92°
August, 1896	10 days	94°
August, 1900	17 days	95°

A particularly uncomfortable feature of the hot spell was the high night temperature. During four successive nights the minimum temperature ranged from 80° to 82°. At no other time in the preceding 30 years has the night minimum exceeded 78°. The normal temperature for the month of August at Baltimore is 75°. During August, 1900, the mean temperature was 80°; this value was equalled but once, namely, in 1872.

The abnormally warm weather of August was not confined to narrow limits. During the first week the temperature was above normal from the Rocky Mountains eastward to the Lower Lakes and the Appalachian

Mountains. In South Dakota the daily excess was 12° above the normal value. During the second week the warm area extended eastward to the Atlantic coast, and the areas of maximum excess were transferred eastward to Michigan and to the region including Philadelphia, Baltimore, and Washington, D. C. The temperature continued abnormally high during the third and fourth weeks, but the maximum daily excess fell from 12° to 9°.

The high temperatures have frequently been attributed in the daily press to a greater solar activity as shown by the increasing number of spots upon the sun's disk. A less remote and more plausible explanation may be found in the unusual distribution of atmospheric pressure during the hot spell. There is a type of pressure distribution which always brings warm weather to the Middle Atlantic states. When the barometer is high over the South Atlantic states, or just off the coast, while it is relatively low over an extensive area to westward and northward, the winds over the Middle Atlantic states are generally from a southerly direction, and light in force, while the skies are clear. Near the center of high pressure, moreover, the air descends from higher levels and is warmed by compression in descending. These conditions, all favorable to the production of high temperatures, were present in a marked degree during the period of hot weather in July and August. Clear skies favored the rapid warming up of the surface of the earth and the adjacent layers of air during the day; and the frequent calms and the prevailing light winds—the average for the entire period of the hot spell being but 4.5 miles per hour at the Baltimore station—prevented the rapid exchange of temperatures between adjacent regions, or between upper and lower layers of the atmosphere. As a result the air near the surface of the earth was excessively heated. At the high level stations of Western Maryland the temperatures were comparatively moderate. The maximum for the month of August was but 89° at Deer Park, and 91° at Grantsville.

General Weather Conditions During the Hot Spell of 1900.

The distribution of pressure and general weather conditions at the beginning of the August hot spell are shown in the chart for August

6, 1900. An extensive area of high pressure which had drifted slowly across the Lake region moved southward, the center being over the Middle Atlantic states on the 5th. The center of the high area remained for nearly two weeks in approximately the same position. Clear skies and light southerly winds were the prevailing conditions in the Middle Atlantic states. Occasionally the center of the high area would be a

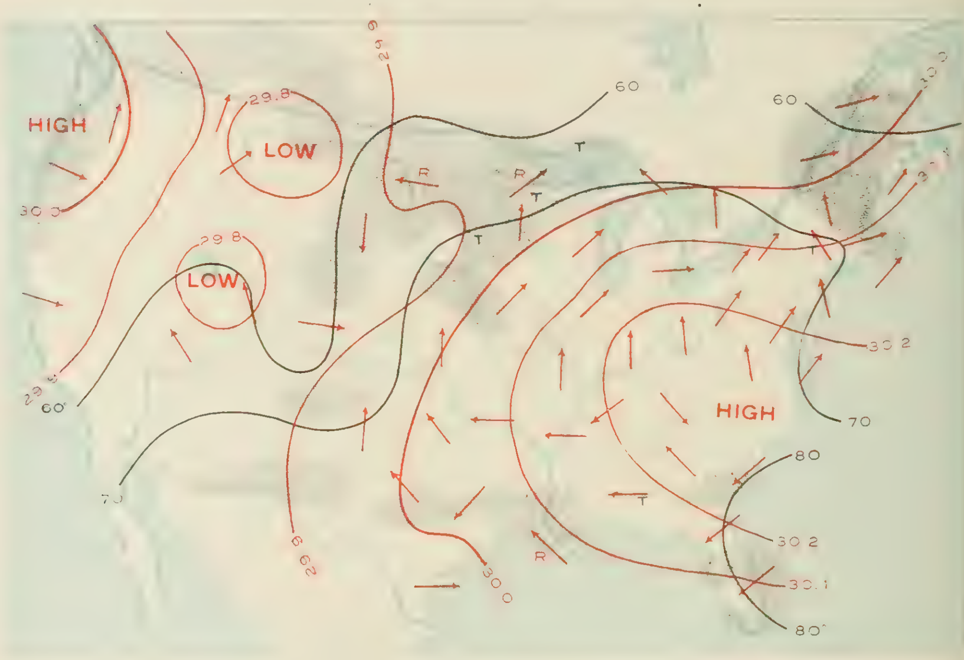

FIG. 161.—Chart of August 6, 1900 (during Hot Spell).

but the atmosphere was drawn from the same source to the south, and little further to the southwest, causing a northwest wind at Baltimore, change in local direction would bring about no change in temperature. Over the Eastern Rocky Mountain slope the pressure remained comparatively low throughout the heated term. On the 12th of August a trough of low pressure developed between the southern high area and an area of high pressure over the Canadian Provinces, causing cloudiness and thunderstorms in the Lake region; this condition developed a

depression over the Lower Lake region on the 13th, attended by showers and thunderstorms as far south as Maryland and Northern Virginia. But the relief brought about by these showers was only temporary. Local showers in connection with thunderstorms also afforded some relief in the Middle Atlantic states, the Ohio and the Missouri valleys on the 16th, but the temperatures soon regained their intensity. On the 19th an area of high pressure developed to the north of the Lake region while the South Atlantic states high area drifted to the southwest and gradually dissipated. In the meantime a trough of low pressure developed between the two high areas in the Middle Atlantic states, bringing clouds and rain and breaking up the general conditions of pressure which caused the hot spell.

The high temperatures of a hot spell are generally first experienced in the Missouri and Mississippi valleys; the distribution of pressure as shown in the chart for August 5 indicates very favorable conditions for a strong drift of warm southerly winds into these valleys. The area of excessive temperatures then moves eastward toward the Atlantic seaboard. This is clearly shown in the accompanying charts which outline the areas over which the temperatures were in excess or deficiency of their normal values for each week from July 23, 1900, to September 24, 1900. (See Plate XXIII.) Beginning with the week ending July 30, we find the line of no departure from the normal temperature for the week passing through Baltimore, and that over practically the entire central portion of the country the temperatures were from 1° to 3° below their normal values. In the accompanying charts, while the line of zero change again passes through Baltimore, the "hot wave" had already been well established in the Upper Missouri Valley where the daily average temperatures were 9° to 12° above their seasonal values. By the close of the following week the area of greatest excess of temperature above the normal was transferred to Maryland, Pennsylvania, and Virginia with a departure of 12° per day above the normal for the season, while the temperatures had somewhat abated in Missouri and Mississippi valleys. The following charts show that the unseasonable temperatures continued without interruption over practically all of the country east of

the Rocky Mountains until the middle of September, the week ending September 24 showing the first appearance of temperatures below the seasonal averages in the northern half of the country, while they still continued high south of the Ohio River.

It is interesting to note in these charts that the area of the hot wave embraced practically all of the country east of the Rocky Mountains, and that west of the mountain range the temperatures were below their seasonal averages. This is generally true of our hot waves, the Rocky Mountains forming a natural boundary between areas of excessive and deficient temperature.

THE SUMMER OF 1901.

During the latter part of June and the first week of July, 1901, a heated term of even greater intensity than that of August of the preceding year occurred, although it was fortunately of shorter duration. Afternoon temperatures exceeding 90° at Baltimore began on June 26 with an area of high pressure centered over the Middle Atlantic states and a barometric depression over the Upper Missouri Valley. The temperature rose steadily until the first of July, reaching a maximum of 103° on the 1st and 2d; from the 3d there was a steady fall in the mean temperature of the day to a normal condition on the 7th, when a thunderstorm accompanied by heavy rain brought on an abrupt fall of 30° in the temperature between 4 o'clock and 4.15 p. m.

The excessive heat began about 10 days earlier in the Central West. During the week ending June 17 the temperature rose to 6° above the normal seasonal value in the Middle Mississippi Valley. In the following week the area of excessive heat embraced all the district between the Rocky Mountains and the Alleghanys, with a maximum departure from the normal still in the Middle Mississippi Valley. By July 1 the area had extended to the Atlantic coast, while the heat was steadily increasing in intensity in the Mississippi Valley and the Lake region to a daily maximum excess of 12° above the normal temperatures. During the following week the center of the heated area was transferred eastward to the Middle Atlantic states with a maximum daily excess of 12° within the

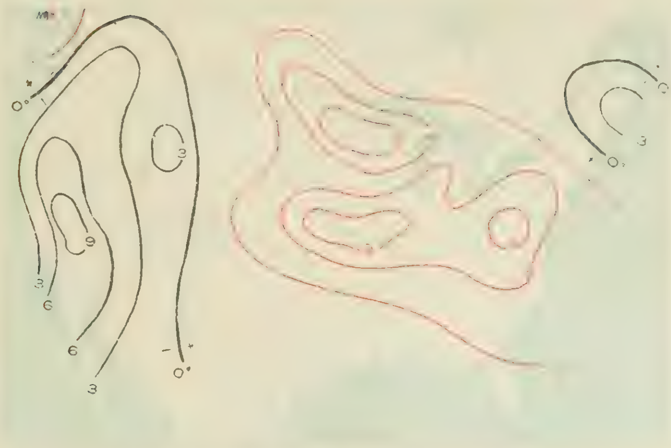

Fig. 4.—Week ending August 20, 1900.

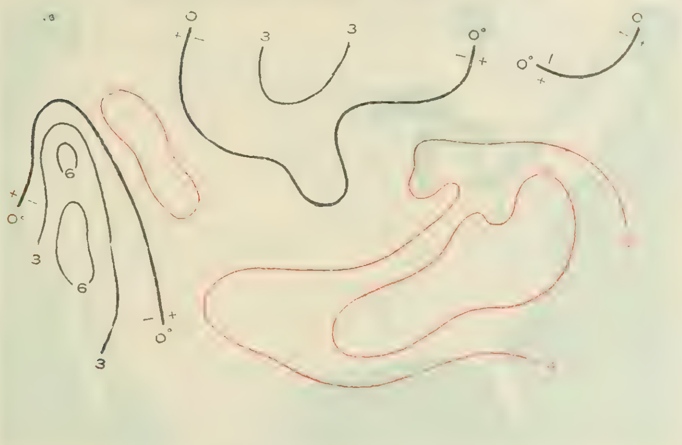

Fig. 8.—Week ending September 17, 1900.

FIGURES 1-9 SHOW

TEMPERATURE DEPARTURES DURING THE HOT SPELL OF 1900.

Black lines show temperature departures below normal during hot spell of 1900.

Red lines show temperature departures above normal during the hot spell of 1900.

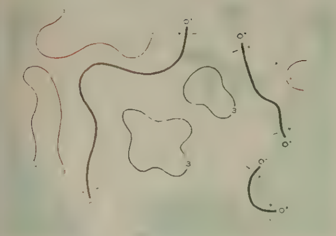

FIG. 1.—Week ending July 30, 1900.

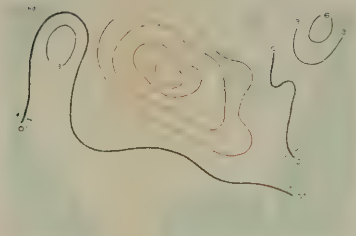

FIG. 2.—Week ending August 6, 1900.

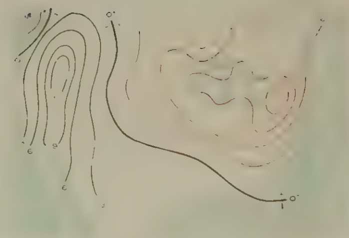

FIG. 3.—Week ending August 13, 1900.

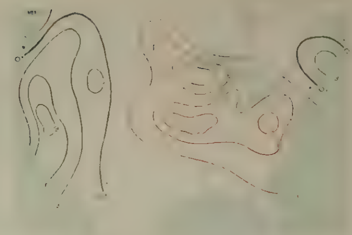

FIG. 4.—Week ending August 20, 1900.

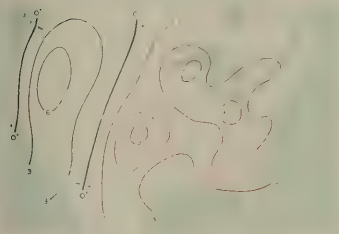

FIG. 5.—Week ending August 27, 1900.

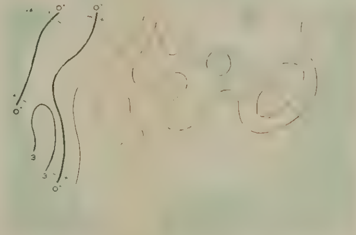

FIG. 6.—Week ending September 3, 1900.

FIG. 7.—Week ending September 10, 1900.

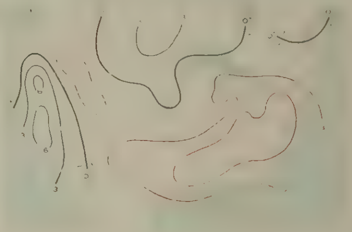

FIG. 8.—Week ending September 17, 1900.

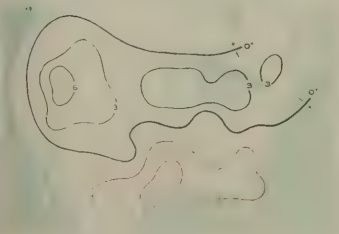

FIG. 9.—Week ending September 24, 1900.

FIG. 10.—Maximum temperatures of July, 1901.

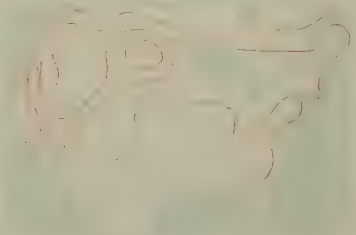

FIG. 11.—Maximum temperatures of August, 1900

FIGURES 1-9 SHOW

TEMPERATURE DEPARTURES DURING THE HOT SPELL OF 1900.

Black lines show temperature departures below normal during hot spell of 1900.

Red lines show temperature departures above normal during the hot spell of 1900.

area embracing Baltimore, Philadelphia, and New York, while the heat had somewhat moderated in the Middle Mississippi Valley. In the 2d week in July the heat was again on the increase in the Middle Mississippi Valley, with moderating temperatures in the Middle Atlantic states and the Ohio Valley. The New England states experienced but little of the excessive heat of this period. In the Middle West during the second week of July maximum temperatures of 102° to 104° were of frequent occurrence, establishing new records for excessive heat in a number of localities. In Baltimore the hot spell continued about 10 days, while the highest temperature, 103° on the 1st and 2d of July, was within 1° of the highest ever recorded at Baltimore.

THE HOT PERIODS OF AUGUST, 1900, AND JULY, 1901, COMPARED.

The two periods of excessive heat described above were the most intense noted in the official records of the Weather Bureau since the establishment of the Baltimore office of the National Bureau. While there were many characteristics in common, the two periods showed a marked difference in their effects upon the residents of Baltimore. The death rate is always increased during a well marked hot spell in the large cities of the country. It is a difficult matter, however, to determine the immediate cause of the increased rate. It can not in general be attributed alone to increase in temperature of these hot spells, though this is probably the dominant factor. The humidity doubtless plays an important part in increasing the number of deaths. Perhaps, also, the weather conditions of the preceding weeks must be taken into account. The hot spell of August, 1900, covered a slightly longer period than that of June-July, 1901; the temperatures also averaged somewhat higher; the wind movement was approximately the same. There was an astonishing difference, however, in the number of deaths reported by the Baltimore Health Department as due directly to heat.

During the 1900 period there were 32 deaths due to heat prostration; in the June and July period of 1901 there were twice as many—namely, 64. The only marked difference between weather conditions noted was the difference in humidity—in 1901 the average daily relative humidity

was 66 per cent of saturation, while in 1900 it was 57 per cent. The August, 1900, period was preceded by excessive temperatures in May and June, though of short duration, and by an exceptionally long and

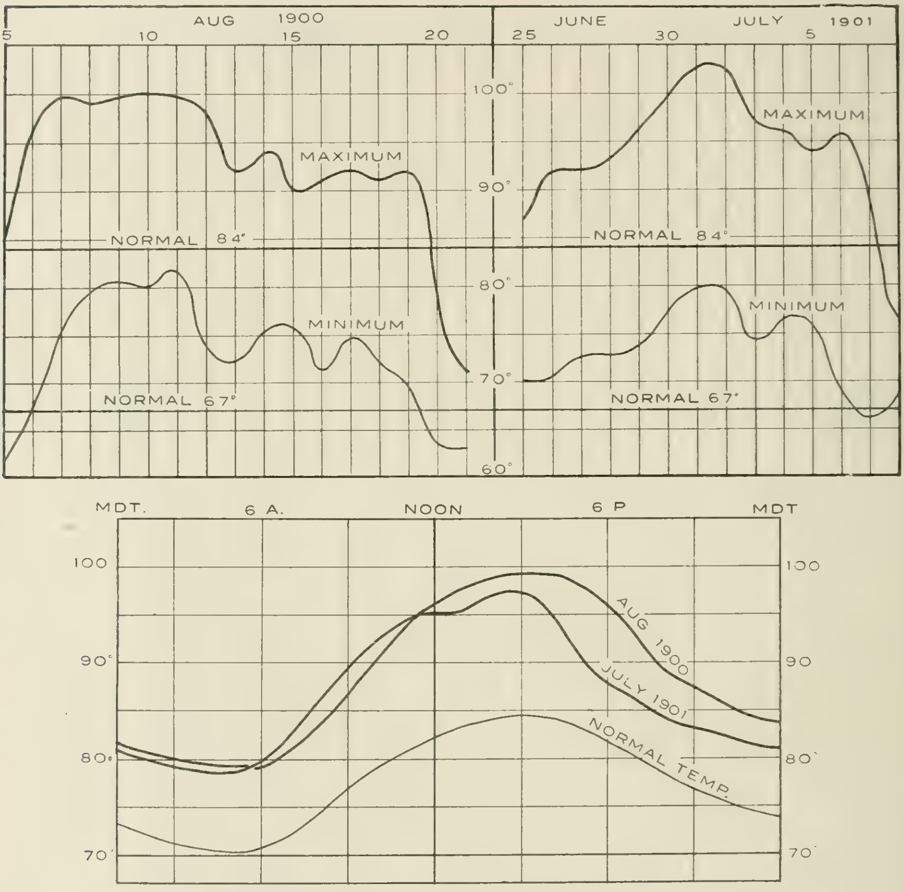

FIG. 162.—Temperature during Hot Spells of 1900 and 1901.

intense, though interrupted, spell in July, which may have increased the powers of resistance and enabled the residents of Baltimore to withstand the debilitating effects of an additional period after the interval of two weeks of moderate summer weather between the 22d of July

and 6th of August. In the case of the hot period of June 26-July 7, 1901, there were practically no excessively hot days in the months of May and the first three weeks of June; the city was overwhelmed without previous preparation, by one of the most intense heated terms experienced in Baltimore.

A comparison of the chief climatic features of the two periods by means of statistics and diagrams will enable the reader to understand more fully the points of difference and similarity.

THE HOT PERIOD OF AUGUST, 1900.

Date.	Max. Temp.	Min. Temp.	Relative Humidity.	Wind Direction.	Hourly Wind Velocity.	Cloudiness.	Rainfall.	Thunder Storms.
	(Degrees Fahr.)		(Per cent.)		(Miles.)			
Aug. 6	97	67	64	SW	2.9	Clear	...	..
" 7	100	76	58	W	4.9	Clear	...	..
" 8	99	80	52	NW	5.5	Pt. cldy	...	..
" 9	100	81	54	W	4.0	Pt. cldy	...	..
" 10	100	80	50	Var.	5.1	Clear	...	..
" 11	100	82	44	W	4.7	Clear	...	..
" 12	99	73	70	W	6.1	Clear	0.14	*
" 13	92	72	63	SW	3.7	Pt. cldy	0.03	..
" 14	94	76	60	SE	4.0	Pt. cldy	...	..
" 15	91	76	72	S	4.3	Pt. cldy	T	*
" 16	92	71	74	W	4.0	Pt. cldy	0.36	*
" 17	91	75	73	N	4.5	Pt. cldy	...	..
" 18	92	72	75	S	3.2	Pt. cldy	...	..
Average	95.0	75.5	62	W	4.4	Pt. cldy	Total 0.53	..

THE HOT PERIOD OF JUNE-JULY, 1901.

Date.	Max. Temp.	Min. Temp.	Relative Humidity.	Wind Direction.	Hourly Wind Velocity.	Cloudiness.	Rainfall.	Thunder Storms.
June 26	92	70	58	SW	3.7	Pt. cldy	...	..
" 27	92	73	60	SW	5.5	Pt. cldy	...	..
" 28	93	73	70	SE	4.0	Pt. cldy	...	..
" 29	96	74	68	SW	5.2	Clear	...	..
" 30	99	77	58	W	3.1	Clear	...	..
July 1	103	80	60	SW	3.6	Pt. cldy	...	..
" 2	103	80	65	Var.	4.5	Pt. cldy	...	..
" 3	97	74	60	SW	4.9	Pt. cldy	T	*
" 4	96	77	66	W	4.3	Pt. cldy	T	*
" 5	94	76	61	SW	5.9	Pt. cldy	...	..
" 6	96	69	76	W	6.0	Pt. cldy	0.65	*
" 7	90	66	83	SW	5.8	Pt. cldy	0.50	*
Average	95.9	74.1	65	SW	4.7	Pt. cldy	Total 1.15	..

THE ANNUAL DISTRIBUTION OF DAYS WITH A MAXIMUM TEMPERATURE OF 90° OR ABOVE.

(Baltimore, Md., 1871-1907.)

Year.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Annual.	Absolute Maximum.
									°
1871	..	..	2	5	2	..	..	9	92, July 16.
1872	..	..	5	10	12	2	..	29	97, July 2.
1873	..	..	2	15	4	2	..	23	96, July 3.
1874	..	..	9	7	3	1	..	20	98, June 9.
1875	..	..	7	7	..	2	..	16	97, June 27.
1876	..	..	5	18	2	..	..	25	99, July 9.
1877	..	2	4	8	3	..	..	17	95, June 26.
1878	..	..	1	16	4	..	..	21	98, July 18.
1879	..	1	4	10	5	..	..	20	99, July 16.
1880	..	7	9	10	2	3	..	31	99, July 13.
1881	..	3	3	11	8	6	..	31	101, Sept. 7.
1882	..	..	6	8	1	..	..	15	97, June 25.
1883	..	..	1	7	2	..	..	10	96, July 22.
1884	..	..	4	3	3	3	..	13	95, July 24.
1885	..	..	4	15	3	..	..	22	99, July 21.
1886	..	..	..	4	4	2	..	10	92, { July 7, Aug. 27
1887	..	..	2	10	3	..	..	15	102, July 18.
1888	1	..	8	5	10	..	..	24	96, Aug. 16.
1889	..	2	2	5	1	..	..	10	93, July 9.
1890	..	..	4	8	2	..	..	14	98, July 8,
1891	..	..	5	..	5	1	..	11	94, { June 16, Aug. 10, 11.
1892	..	..	6	10	3	..	..	19	99, July 26.
1893	..	..	5	9	2	..	..	16	98, June 20.
1894	..	..	8	11	2	2	..	23	98, June 24.
1895	..	2	5	5	10	7	..	29	97, June 1, 3.
1896	2	5	3	10	10	3	..	33	98, Aug. 7.
1897	..	..	2	4	1	4	1	12	97, Sept. 11.
1898	..	1	7	10	9	8	..	35	104, July 3.
1899	..	1	8	8	8	2	..	27	98, June 6.
1900	..	3	3	15	17	4	..	42	100, { July 16, 17. Aug. 7, 9, 10, 11.
1901	..	..	6	18	1	1	..	26	103 July 1, 2.
1902	..	1	4	10	1	1	..	17	99 July 18.
1903	1	1	..	10	2	..	..	14	94 Aug. 25.
1904	..	..	4	6	..	..	..	10	97 July 19.
1905	..	..	4	8	1	..	..	13	98 July 18.
1906	..	2	5	3	4	2	..	16	96 Aug. 6.
1907	..	..	1	6	3	1	..	11	93 July 8, 11.
Totals	4	31	158	325	153	57	1	729	
Average	..	1	4	9	4	2	..	20	

The Cold Summer of 1816.

There are numerous records in local annals showing that the summer of 1816 was phenomenally cold—in fact the coldest of which we have any authentic records. Systematic instrumental observations did not begin in Baltimore until the year 1817 (see pages 91-95); however, it is not a difficult matter to reduce reliable records of a neighboring station to contemporary conditions in Baltimore. We fortunately have a very complete and trustworthy series of daily records for Philadelphia, which go back to the year 1790.

In the main, weather changes in Philadelphia and Baltimore are synchronous, and similar in kind; there is, however, a uniform difference of 1° to 2° in the average monthly temperatures of the two stations due to difference in latitude. By adding this difference to the average monthly Philadelphia temperatures we obtain a reliable value for contemporary Baltimore temperatures.

An interesting little book published in Philadelphia in 1847 by Mr. Charles Peirce and entitled "A meteorological account of the weather in Philadelphia from 1790 to 1847," contains a valuable record of the general weather conditions for each month during this period of 57 years.

The following extracts are made concerning the character of the weather conditions in 1816, with special reference to the three summer months of June, July, and August:

The Year. The temperature of the whole year was only 49°; it being the coldest year we have on record. Although there was no uncommonly cold weather during the three winter months, yet there was ice during every month in the year, not excepting June, July, and August. There was scarcely a vegetable came to perfection north and east of the Potomac. The cold weather during summer, not only extended through America, but throughout Europe. It was also the coldest summer ever known in the West Indies and in Africa.

June, 1816. The medium temperature of the month was only 64°, and it was the coldest month of June we ever remember; there were not only severe frosts on several mornings, but on one morning there was said to be ice. Every green herb was killed, and vegetables of every description very much injured. All kinds of fruit had been previously destroyed, as not a month had passed without producing ice. From 6 to 10 inches of snow fell in

various parts of Vermont; 3 inches in the interior of New York; and several inches in the interior of New Hampshire and Maine.

July, 1816. The medium or average temperature of this month was only 68°, and it was a month of melancholy forebodings, as during every previous month since the year commenced, there were not only heavy frosts, but ice, so that very few vegetables came to perfection. It seemed as if the sun had lost his warm and cheering influences. One frosty night was succeeded by another, and thin ice formed in many exposed situations in the country. On the morning of the 5th there was ice as thick as window glass in Pennsylvania, New York, and through New England. Indian corn was chilled and withered, and the grass was so much killed by repeated frosts, that grazing cattle would scarcely eat it. Northerly winds prevailed a great part of the month; and when the wind changed to the west, and produced a pleasant day, it was a subject of congratulation by all. Very little rain fell during the month.

August, 1816. The medium temperature of this month was only 66°, and such a cheerless, desponding, melancholy summer month, the oldest inhabitant never, perhaps, experienced. This poor month entered upon its duties so perfectly chilled, as to be unable to raise a warm, foggy morning, or cheerful sunny day. It commenced with a cold northeast rain storm, and when it cleared the atmosphere was so chilled as to produce ice in many places half an inch thick. It froze the Indian corn, which was in the milk, so hard, that it rotted up on the stock, and farmers mowed it down and dried it for cattle fodder. Every green thing was destroyed, not only in this country, but in Europe. Newspapers received from England said: "It will be remembered by the present generation, that the year 1816 was a year in which there was no summer." Indian corn, raised in Pennsylvania in 1815, sold (for seed to plant in the spring of 1817) for four dollars per bushel in many places.

The departures of the year 1816 from the normal summer temperature are compared with the departures for some of the coolest summers on record in Baltimore in the following table:

DEPARTURES FROM THE NORMAL TEMPERATURE.

	June.	July.	August.	Season.
1816	—8°	—8°	—8°	—8.0°
1836	—5°	—3°	—5°	—4.3°
1846	—4°	—3°	—1°	—2.7°
1886	—3°	—3°	—2°	—2.7°
1891	—1°	—6°	—2°	—3.0°
1903	—6°	—1°	—3°	—3.3°

The mean daily temperature for each month of the summer of 1816 fell decidedly below that of any summer month during the period of observations—from 1790 to 1906.

Distribution of Pressure During the Cool June of 1903.

In the normal distribution of pressure during the summer months the western edge of the Atlantic high area extends to the South Atlantic states while the barometer over the Central states is comparatively low. Hence the atmosphere which flows over the Middle Atlantic states comes from the warm southeast. In June of 1903 the barometer was comparatively high over the North-Central states, with a maximum in the Upper Mississippi and in the Missouri valleys, and relatively low in the Lower Lake region and the Atlantic coast states. During the same period the western portion of the Atlantic high area was found far northward toward the Gulf of St. Lawrence, causing cool easterly in place of the usual warm southerly winds to blow over the Middle Atlantic states; in addition an unusual flow of cool air was derived from the high area to the northwest over the central portion of the North American continent. The effect of this abnormal distribution of pressure is reflected in the temperature departures recorded in the following table:

COOL JUNE OF 1903.

Districts.	Normal Temp.	Departure.
New England States	57.8°	—5.4°
Middle Atlantic States	65.7°	—5.2°
South Atlantic States	73.4°	—3.2°
Gulf States	74.5°	—4.5°
Ohio Valley and Tennessee	68.4°	—5.6°
Lake Region	60.8°	—3.8°

At Baltimore the month was cool, wet, and cloudy. The afternoon temperatures were high on a number of days, but the warm periods were of brief duration. Light frosts occurred in the mountains at the beginning of the month. The rainfall was considerably in excess of the normal seasonal amounts. The mean temperature of the month was 67.5°, 5.8° below the average value for a period of 86 years. This large departure from the average June temperature in Baltimore marks the month of June, 1903, as the coldest since the beginning of systematic instrumental observations in 1817. (See Pl. XXIV.)

Distribution of Pressure During the Normal June of 1902.

The temperatures during the month of June, 1902, were very near the normal for a long series of years; they were remarkably uniform, the month being without marked departures from the seasonal average either above or below the normal. The distribution of pressure was in marked contrast with that of the cool June of 1903, described in the preceding paragraphs. The pressure was highest over the South Atlantic states and low over the St. Lawrence Valley and the extreme Southwest. The pressure distribution was such as to give prevailing southwest winds over the Middle Atlantic states. (See Pl. XXIV.)

While the immediate cause of departures from the normal seasonal temperatures over wide areas may be traced back to abnormal distribution of pressure, it is not so easy to find a cause for these abnormal movements in the positions of the so-called permanent areas of high and low pressure. This slow shifting about of the large areas of high and low barometric pressure is sufficient cause for the greatest observed departures from the seasonal temperature of a given locality, without calling in the aid of extra-terrestrial influences, such as the moon, the planets, or sun-spots.

The Variability of Summer Temperatures.

While marked temperature changes from day to day during the summer months are not as frequent or as large as they are during the winter and spring seasons, there is still considerable variability due to the different types of pressure distribution. With a pronounced area of high pressure over the Upper Mississippi Valley and the Lake region the temperatures in the Middle Atlantic states fall below the seasonal average; with a well developed high area over the South Atlantic states, or just off the coast to the southeast, the temperatures over the Middle Atlantic and the Central states rise above the normal. These two types of pressure distribution, with resulting departures from the normal seasonal temperatures, are well defined in the weather maps of July 1, 1885, and July 1, 1901. On the 1st of July, 1885, an area of high pressure cov-

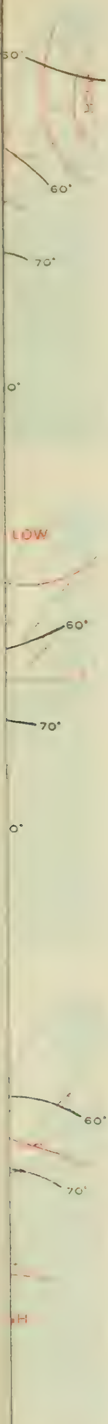

Fig. 10.—Cold October, 1905 (—4°).

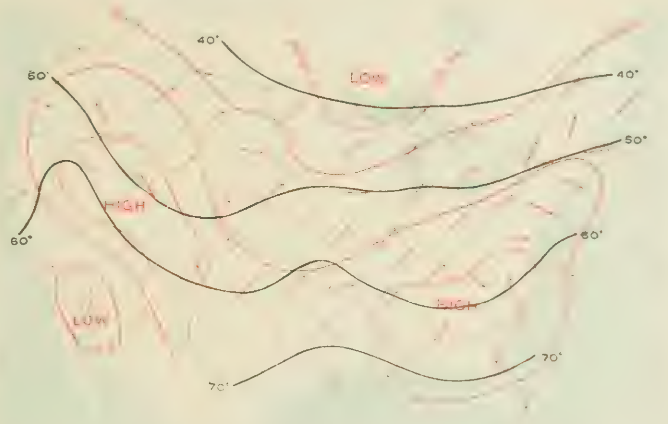

Fig. 11.—Normal October, 1894 (—0°.1).

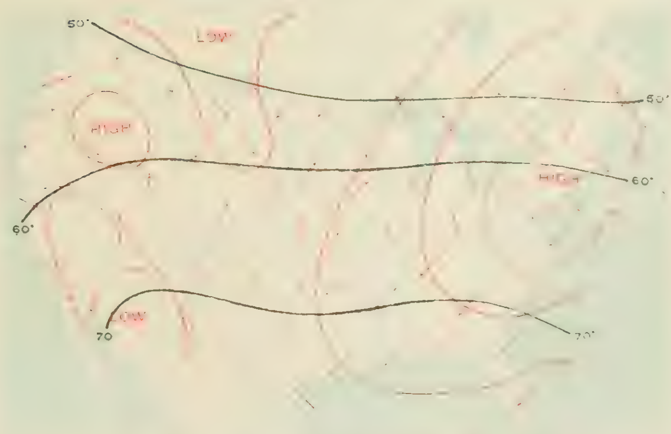

Fig. 12.—Warm October, 1900 (+4°.5).

D States.

sobars, or lines of equal pressure

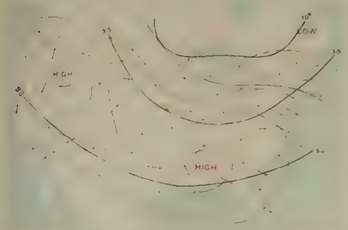

Fig. 1.—Cold December, 1903 (—4°.2).

Fig. 4. Cold March of 1883 (—2°.6).

Fig. 7.—Cold June of 1903 (—6°).

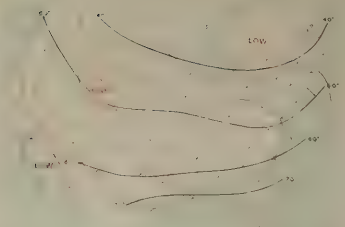

Fig. 10.—Cold October, 1905 (—4°).

Fig. 2.—Normal December, 1888 (+0°.1).

Fig. 5.—Normal March of 1886 (—0°.4).

Fig. 8.—Normal June of 1902 (—0°.1).

Fig. 11.—Normal October, 1894 (—0°.1).

Fig. 3. Warm December of 1889 (+8°.0)

Fig. 6. Warm March of 1898 (+6°.5)

Fig. 9. Warm June of 1899 (+2°)

Fig. 12. Warm October, 1900 (+4°.5)

DISTRIBUTION OF PRESSURE, WINDS AND TEMPERATURE DURING NORMAL, COLD AND WARM SEASONS IN THE UNITED STATES.

Black lines are isotherms, or lines of equal temperature.

Red lines are isobars, or lines of equal pressure

Arrows fly with the wind.

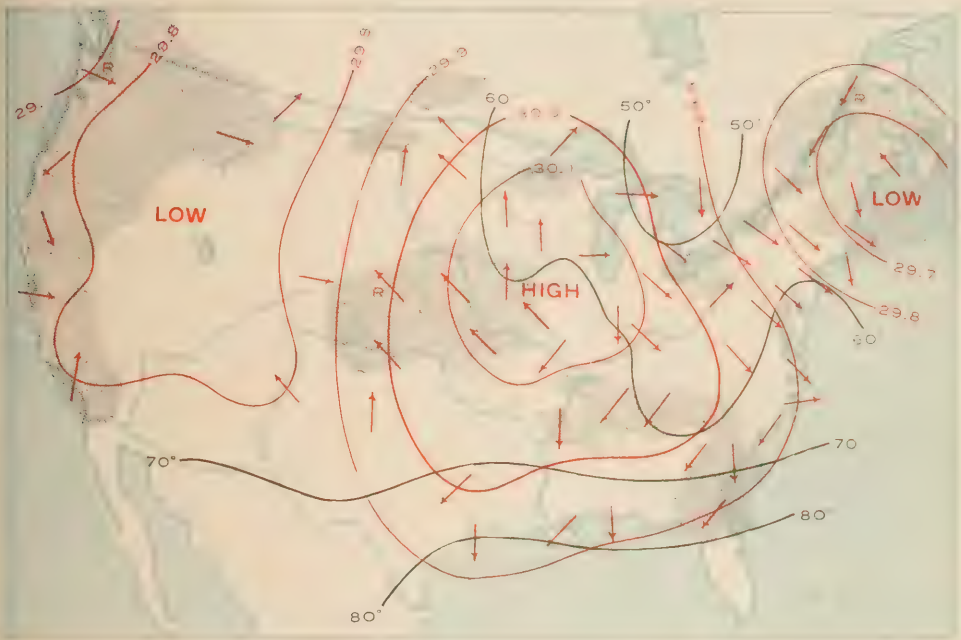

FIG. 163.—The Cold July 1, 1885.

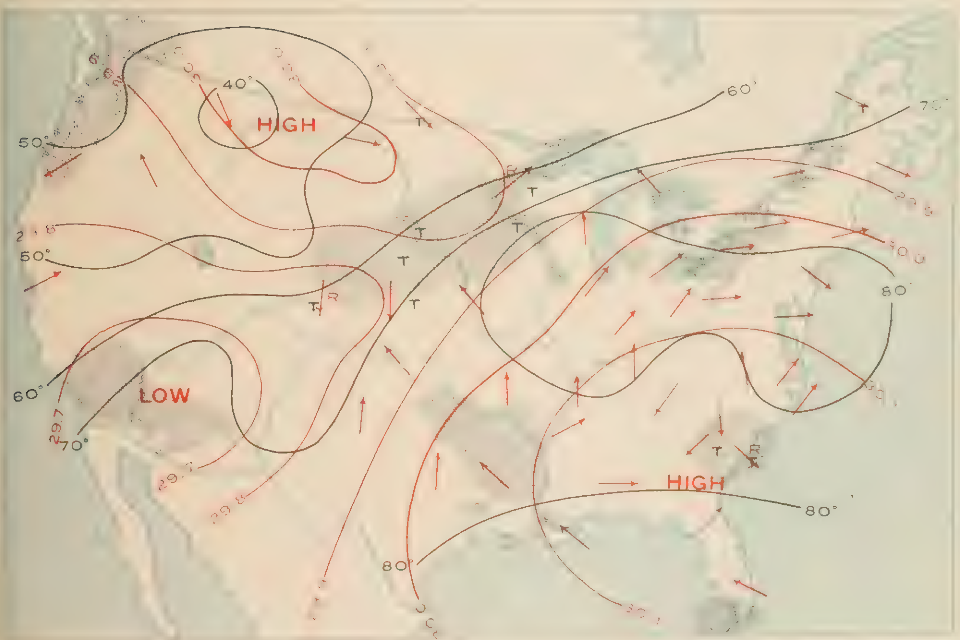

FIG. 164.—The Warm July 1, 1901.

ered most of the country east of the Rocky Mountains, excepting the New England states, the barometer being highest over the Middle Mississippi Valley. This distribution of pressure caused a steady flow of cool northwest winds over the Middle Atlantic states. The temperatures for the day were abnormally low. The early morning minimum at Baltimore was 56°, the lowest minimum recorded on the first day of July in a period of 36 years. The distribution of pressure noted above is typical for periods of cool weather in all seasons of the year.

TEMPERATURES ON JULY 1, 1885.

(A cool day with high barometer in Northwest.)

7 a. m.	3 p. m.	11 p. m.	Max.	Min.
62	76	68	79	56
		Mean 67.5°		

On the other hand the warm weather type is represented by the distribution of pressure seen in the weather map showing conditions on the morning of July 1, 1901.

In this type the high area covers the South Atlantic states. With such a distribution of pressure the winds in the Middle Atlantic states are light and prevailingly from the south or southwest and abnormally warm. The minimum temperature on this day at Baltimore was 80°, while the afternoon maximum reached 103°, the highest recorded in Baltimore upon the first day of July.

TEMPERATURES ON JULY 1, 1901.

(A warm day with high barometer in the Southeast.)

Hours.	2	4	6	8	10	12	
A. M.	82	81	82	88	96	102	Noon
P. M.	103	99	96	91	88	87	Midnight
			Mean 90.9°				

THE WEATHER OF JULY 4.

The variability of weather conditions may be illustrated in another way, by charting the various climatic factors for a given typical summer day during a long series of years. Thus in the accompanying diagram we have noted the maximum, the mean, and the minimum temperatures, the barometric pressure, the amount of cloudiness, the prevailing wind direction and the amount of rainfall recorded upon each fourth of July

THE WEATHER OF JULY 4.

Year.	Max. Temp.	Min. Temp. (Degrees Fahr.)	Mean Temp.	Character of Day.	Wind Direction.	Daily Wind Movement. (Miles)	Precipitation. (Inches)
1871	82	71	76	Pt. cldy	E & SW	120	0.03
1872	93	78	86	Pt. cldy	SW	117	0.05
1873	92	76	84	Cloudy	W	168	...
1874	92	67	80	Cloudy	S & W	100	1.14
1875	83	69	76	Cloudy	SE	137	..
1876	95	73	84	Pt. cldy	SW	103	0.22
1877	86	70	78	Pt. cldy	N	185	...
1878	92	73	82	Clear	SE	127	...
1879	98	74	86	Pt. cldy	SW & W	170	...
1880	87	66	76	Clear	N	145	...
1881	93	74	84	Cloudy	NW	137	...
1882	71	61	66	Cloudy	NE	178	1.09
1883	94	74	84	Clear	SW	207	...
1884	85	73	79	Cloudy	E-SE-S	115	0.04
1885	88	65	77	Clear	N & NW	85	...
1886	86	66	76	Pt. cldy	N-E-S	70	..
1887	86	72	79	Cloudy	SE	212	...
1888	85	64	74	Pt. cldy	S	143	...
1889	84	74	79	Cloudy	SW	143	0.36
1890	91	71	81	Pt. cldy	SW & NW	77	...
1891	79	59	69	Pt. cldy	W & NW	324	0.08
1892	75	61	68	Pt. cldy	W & NW	191	...
1893	84	64	74	Clear	NW	155	0.01
1894	86	72	79	Pt. cldy	W	243	...
1895	76	64	70	Cloudy	NW	169	0.11
1896	88	70	79	Cloudy	SW	177	...
1897	86	72	79	Pt. cldy	E	138	...
1898	100	74	87	Pt. cldy	SW	102	0.07
1889	90	68	79	Pt. cldy	S	115	...
1900	97	77	87	Pt. cldy	SW & W	114	...
1901	96	77	86	Pt. cldy	W	103	...
1902	86	70	78	Cloudy	S	117	0.17
1903	87	73	80	Cloudy	SE	123	0.08
1904	88	61	74	Clear	SW	156	...
1905	83	69	76	Pt. cldy	SE	204	...
1906	85	73	79	Pt. cldy	SW & W	217	0.02
1907	78	59	68	Clear	N & E	121	...
Average	87	70	78			150	0.25

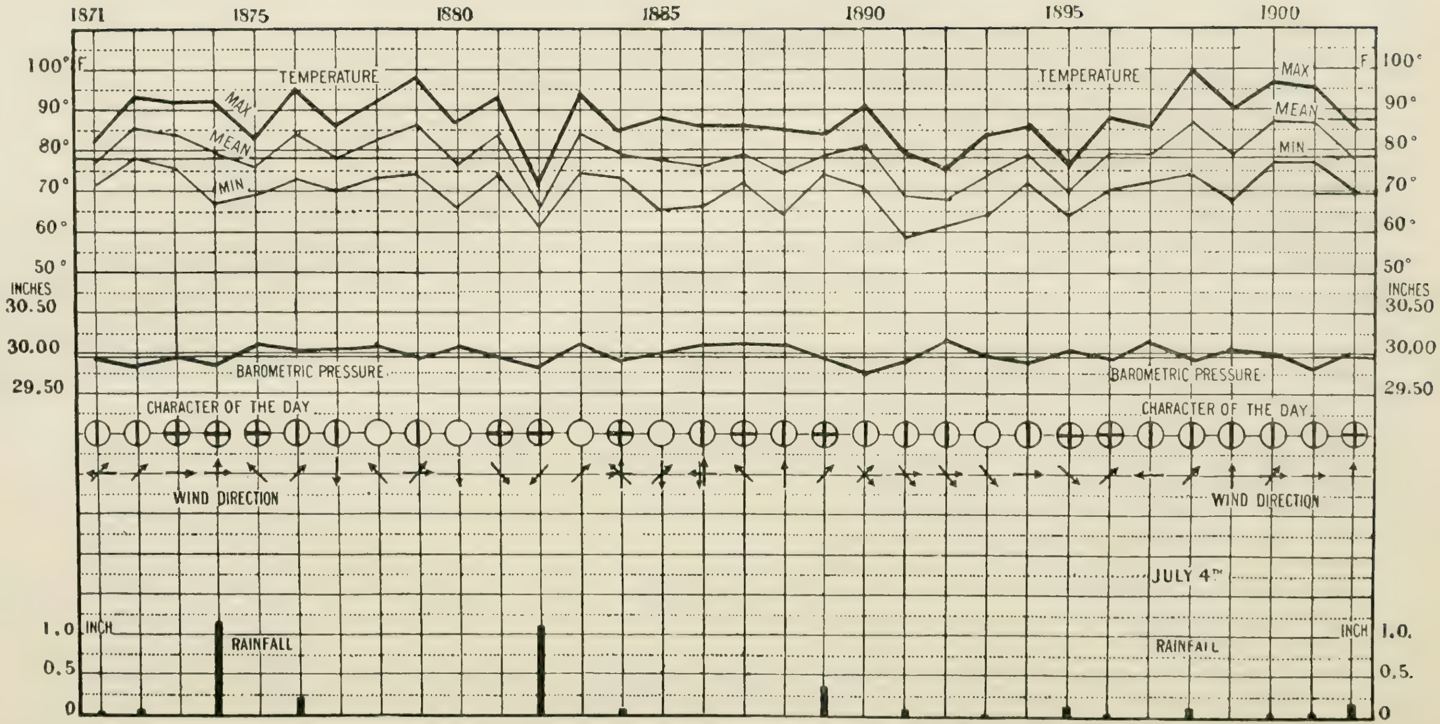

Fig. 165.—The Weather of July 4.

from 1871 to 1903. We see that the lowest temperature recorded on any 4th of July was 58° and that this occurred in 1891; the highest temperature, namely 100°, is credited to 1898. Between these extremes we have had in the past 36 years all degrees of temperature conditions. There appears to be no regularity in the fluctuations in temperature from year to year, although there are indications of irregular periods of steadily decreasing or increasing temperature.

The barometric pressure has varied but little above or below the normal seasonal values, the entire range being less than half an inch.

The days with a clear sky have numbered but six in 36 years; with partly cloudy sky, 18; and with an overcast sky, 12. The prevailing wind direction has been from the southwest. Rain fell in amounts varying from a light sprinkle to heavy showers on somewhat less than half the total number of days, making the rainfall probability for the 4th of July less than 50 per cent. Thunderstorms were recorded but five times during the period of 36 years on this day.

West Indian Hurricanes.

Hurricanes do not differ, in essential features, from the temperate region cyclones described in preceding pages. They are more restricted in area, but relatively more intense in energy and destructive power. These storms have their origin in the vicinity of the Windward Islands; they move toward the west or northwest at the rate of 10 to 12 miles per hour—less than half the average rate of temperate region cyclones—and curve northward and then northeastward approximately in the neighborhood of Florida, as a rule, following the Atlantic coast, enlarging in area after recurving until they resemble in every detail the storms common to the higher latitudes.

While these, the most disastrous of all storms, have occurred in all seasons of the year, they are confined almost entirely to the months of August, September, and October. The abrupt increase in their frequency in August is phenomenal as shown in the following extract from one of the publications of the United States Weather Bureau.[1]

[1] E. B. Garriott. West Indian Hurricanes. Bull. H., U. S. Weather Bureau. 4to. Washington, D. C., 1902.

FREQUENCY OF HURRICANES (1878-1900).

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
3	0	0	0	1	3	3	25	25	32	3	3	98

Fortunately the path of the hurricane rarely falls within the limits of the Middle Atlantic states until it has lost some of its violence. By the time it has reached the latitude of Baltimore the center is generally well off the coast, and we experience only the ordinary storm winds of the western quadrant of the hurricane.

When there happens to be a well developed area of high barometric pressure over the eastern half of the country on the approach of a hurricane the storm is prevented from recurving near the Florida Peninsula and moves slowly westward into the Gulf of Mexico, or even entirely across the Gulf, before recurving northward. Under such circumstances the hurricane is apt to gather in force in its journey across the Gulf. The storm which destroyed Galveston in September, 1900, was of this type.

A typical storm of this class passed over Maryland on the 13th of October, 1893; it is described in the following paragraphs.

THE HURRICANE OF OCTOBER 13, 1893.

The first indication of the approach of this storm from the West Indies was contained in a report from Saint Thomas on the 5th of October; on the following day additional information was received from Antigua. The storm advanced slowly westward.[1] On the 7th it was southeast of Port au Prince, and on the 8th southeast of Santiago de Cuba. On the 9th it had reached the Bahama Islands and Southern Florida, and storm signals were ordered up along the Florida and east Gulf coasts by the Chief of the Weather Bureau. By the evening of the 10th the wind had freshened to a gale along the Florida coast. On the morning of the 11th the storm center was east of the Bahama Islands and the barometer was falling rapidly along the Atlantic coast as far north as New Jersey. During the 12th severe northeast gales and heavy

[1] *See:* Lake Storm Bulletin. No. 2, 1893, U. S. Weather Bureau.

rains prevailed along the coast of the South Atlantic states in connection with a rapidly falling barometer.

On the morning of the 13th the storm center reached the South Carolina coast, the barometer at Charleston indicating 28.88 inches. From this point the storm took an unusual course, moving northward into the interior, the center passing over the Carolinas and the Middle Atlantic states. Northeast storm signals were ordered for all stations on the Middle Atlantic and New England coasts. Special warnings were sent to all Weather Bureau observers in the Middle Atlantic states and New England, and observers from Southern New England to Maryland were authorized to use the telegraph at their discretion in distributing these warnings in the most effectual manner possible.

During the evening of the 13th the center of the storm passed over Western Maryland, the barometer falling to 28.88 inches at Baltimore. Moving due north it crossed Pennsylvania and Western New York to the north of Lake Ontario on the 14th. On the 15th the storm disappeared in the direction of Labrador.

The storm was attended by high winds and heavy rains all along its path across the United States. Some of the records are quoted below from the official report of the United States Weather Bureau.

HIGH WINDS AND HEAVY RAINS DURING THE STORM OF OCTOBER 13 AND 14, 1893.

(8 a. m. to 8 p. m. October 13.)

Station.	Velocity. (Miles)	Direction.	Station.	Velocity. (Miles)	Direction.
Jacksonville, Fla.	38	SW	Harrisburg, Pa.	36	E
Charleston, S. C.	42	NW	Atlantic City, N. J.	38	SE
Atlanta, Ga.	38	W	Philadelphia, Pa.	48	SE
Wilmington, N. C.	56	SE	New York City	30	SE
Raleigh, N. C.	36	E	Cleveland, O.	48	NE
Southport, N. C.	80	SE	Erie, Pa.	30	NE
Washington, D. C.	42	SE	Baltimore, Md.	38	SE

RAINFALL.

Station.	Inches.	Station.	Inches.
Raleigh, N. C.	2.08	Baltimore, Md.	1.00
Lynchburg, Va.	1.66	Pittsburg, Pa.	1.01
Washington, D. C.	1.82	Parkersburg, W. Va.	2.48

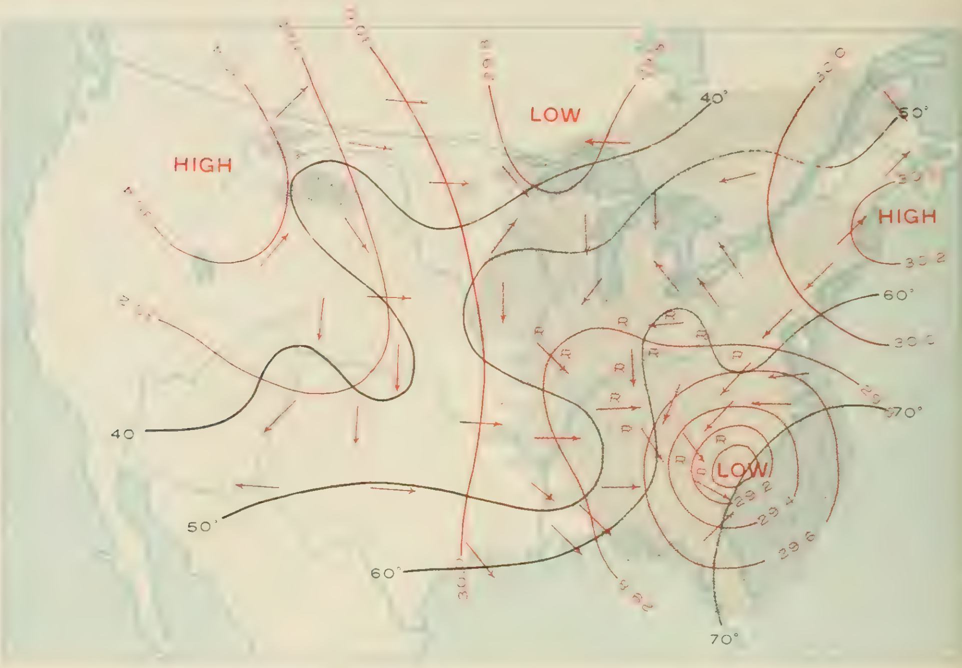

FIG. 166.—The Hurricane of October 13, 1893 (8 a. m.).

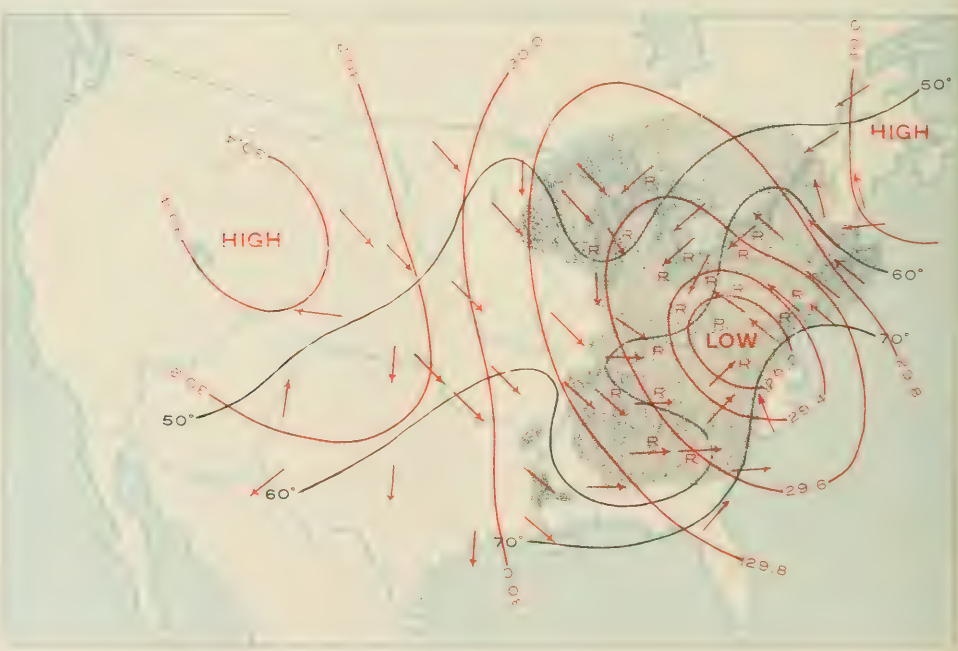

FIG. 167.—The Hurricane of October 13, 1893 (8 p. m.).

(8 p. m. Oct. 13 to 8 a. m. Oct. 14.)

Station.	Velocity. (Miles)	Direction.	Station.	Velocity (Miles)	Direction.
Charleston, S. C.	34	W	Albany, N. Y.	48	SE
Washington, D. C.	42	SE	Oswego, N. Y.	60	SE
Baltimore, Md.	40	SE	Buffalo, N. Y.	60	SW
Atlantic City, N. J.	44	SE	Erie, Pa.	36	SE
Philadelphia, Pa.	56	SE	Sandusky, O.	36	NW
Sandy Hook, N. J.	64	SE	Detroit, Mich.	46	W
Boston, Mass.	36	E	Grand Haven, Mich.	36	NW
Woods Holl, Mass.	44	SE	Marquette, Mich.	34	NW

FIG. 168.—The Hurricane of October 14, 1893 (8 a. m.).

BAINFALL.

Station.	Inches.	Station.	Inches.
Philadelphia, Pa.	1.24	Alpena, Mich.	1.08
Cleveland, O.	1.90	Port Huron, Mich.	1.50

The meteorological conditions as recorded at the Baltimore Office of the Weather Bureau are indicated in the accompanying diagram and in the following extracts from the records of the office:

The barometer reached its lowest point, 28.88 inches, at 10 p. m. of the 13th, then slowly rose throughout the night and following day. Light rain began to fall with a northeast wind and continued without interruption until midnight. The total amount of precipitation was 1.60 inch. The maximum wind velocity, 40 miles per hour from the southeast, occurred during the night of the 13th-14th just before the barometer began to rise, at the time of heaviest rainfall. The temperature rose slowly and steadily from a minimum of 56° at 6 a. m. to 73° at midnight, as the wind gradually veered from northeast to southeast, obliterating the usual diurnal fall after 3 p. m.

The following morning began with a clear sky and a fresh southwest wind, the storm having passed northward beyond the horizon of Baltimore.

AUTUMN WEATHER.

Although the months of June, July, and August only are allotted to the summer season in the division of our calendar, the weather of the month of September in the Middle Atlantic states is truly summer weather. The temperatures continue high; the mean monthly temperature is occasionally higher than the mean monthly value for June, July, or August, while the greatest heat of the summer has on at least two occasions within the past 35 years fallen within the first half of the month. As stated in an earlier paragraph (page 78) the temperature falls more slowly in autumn than it rises in the spring months. There is a striking difference in the mean temperature of the equinoctial days of spring and fall, the latter being 23° warmer than the former. The wind movement is less than that of any other month of the year, excepting August, in spite of the reputation as a month of equinoctial storms.

AVERAGE DAILY WIND MOVEMENT AT BALTIMORE (1873-1903).

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
145	162	175	166	149	142	134	122	129	137	143	142	145 mls

Hence the month of September is about as free from atmospheric disturbances as any portion of the year. The period of the autumnal equinox is quite as free from storm and rain as the days immediately preceding and following. The wind movement, the rainfall probability, and the amount of rain for the 21st and 22d are all below the average for the period from the 15th to the 25th. In view of the figures in the following table it is difficult to find any support for the existence of a particularly stormy period at the time of the September equinox.

WINDS AND RAINFALL FROM SEPTEMBER 15-25.

(Average of 35 years at Baltimore.)

	Wind.	Rainfall.	
	Movement.	Probability.	Daily Average Amount.
	(Miles)	(Per cent.)	(Inch)
September 15	139	45	0.60
" 16	138	37	0.78
" 17	133	40	0.80
" 18	130	30	0.15
" 19	121	27	0.90
" 20	133	28	0.21
" 21	130	27	0.15
" 22	129	32	0.28
" 23	130	35	0.52
" 24	133	25	0.30
" 25	134	30	0.43
Average	132	32.4	0.47

The months of October and November give us some of the most delightful days of the year—days with soft, balmy atmosphere, light southerly winds, cloudless skies with warm sunshine during mid-day, and cool crisp nights—the days of the American Indian Summer.

In Maryland light frosts make their first appearance about the middle of October, excepting in the mountain districts where they are earlier, while heavy frosts are usually delayed to the early days of November. The first snow arrives about the middle of November.

In the fall months the process of redistribution of barometric pressure over ocean and continent is the reverse of that of the spring. The summer condition of high barometric pressure over the Atlantic Ocean and low pressure over the central continental area is gradually broken up, the pressure rising over the continent and falling over the ocean. In this process of redistribution of pressure which is brought about by the retreat of the sun, the sluggish atmospheric movements of the summer months give way to a more active circulation. Well defined areas of high and low pressure increase in frequency. The Middle Atlantic states are alternately brought under the influence of the Atlantic high area with its southerly winds and clear skies, and the cool dry northwest winds of the growing continental high area, but it is not until late in

December that the continental high area gains control over the weather situation in Maryland, and settled winter conditions may be expected.

Indian Summer.

In discussing weather types in the preceding pages we have found a natural division into cyclonic and anti-cyclonic weather—or the weather are relatively low, and those associated with relatively high barometric pressure. The weather conditions attending these moving or shifting pressure areas vary with the season, or rather with the annual increase and decrease in temperature resulting from changes in the declination conditions associated with large areas over which the barometer readings of the sun. But in all seasons high areas are attended by comparatively clear skies and moderate winds, while low areas bring clouds and rain and relatively high winds—they are respectively "fair weather" and "foul weather" types. The temperatures of a given locality associated with these types depend upon the season of the year and the relative position of the center of the high or low area with respect to the locality in question. The relative distribution of pressure determines the wind direction while the wind direction determines the temperature. In our latitudes, and especially over large continental areas with the broad ocean of equable temperatures to the east, a north or northwest wind is a relatively cold wind, a south or southeast wind is relatively warm, at all seasons of the year, while east winds and west winds bring intermediate temperatures. Hence an area of high pressure to the west or northwest of the Middle Atlantic states, for instance, with its resulting northwest to north winds gives to this section in all seasons a temperature below the seasonal average, the amount of departure from the normal depending upon the intensity of development of the high area. With a high area to the east or southeast the winds blowing out of the high area and over the Middle Atlantic states are from the southeast to southwest—winds which are at all seasons warmer than the seasonal average. On the other hand a low area to the west or north brings warm southerly winds; when it is to the south or east the winds are from the colder areas of the north and northwest.

Under normal conditions there is a constant succession of these high and low areas across the country, approximately from the west towards the east, with an irregular cycle of two, three, or four days. Sometimes these types are quite persistent, the pressure distribution remaining practically unaltered for a week or ten days, or longer in exceptional cases. In mid-summer an area of high pressure developing over the South Atlantic states, or over the Atlantic just off the coast, is apt to persist for many days with only slight changes in outline or intensity, resulting in "hot spells" of greater or less degree, depending upon the intensity of development and persistence of this high area to the southeast.

A similar type of high area frequently, though not annually, develops late in the fall after the summer has passed and after the first frosts have announced the approach of winter. The development may occur in the latter part of October or in November, sometimes even later in the season, and controls the weather conditions in the Central, Middle Atlantic and New England states for several days, or at rare intervals, for several weeks.

During the periods in which these southeast anti-cyclonic areas prevail, light dry southerly winds blow over the Middle Atlantic states, the New England states and the Central states, there is an absence of clouds, haze increases in amount, as is usual during warm periods with a sluggish movement of the air; the mid-day temperatures are high, while the nights are cool. Separated from the long season of hot sultry summer weather by occasional incursions of the cold crisp air from a northwest high area, these periods of Indian Summer, or second summer, are among the most delightful days of the year. They constitute a temporary halt in the steady seasonal fall of temperature and the approach of real winter weather. There are similar periods in European weather but there the characteristic charm of the American Indian Summer appears to be less pronounced; of such among others are St. Martin's Summer of England; the Summer of St. Denis in France; and in Germany the "Altweibersommer," or the "old woman's summer."

A most interesting and instructive account of the occurrence of the term "Indian Summer" in the literature of the early writers on America is presented by Mr. Albert Matthews[1] of Boston. The author finds after an exhaustive search in books on travel in North America that "it is not until the year 1794 that the expression 'Indian Summer' occurs at all, and not until the nineteenth century that it became well established."

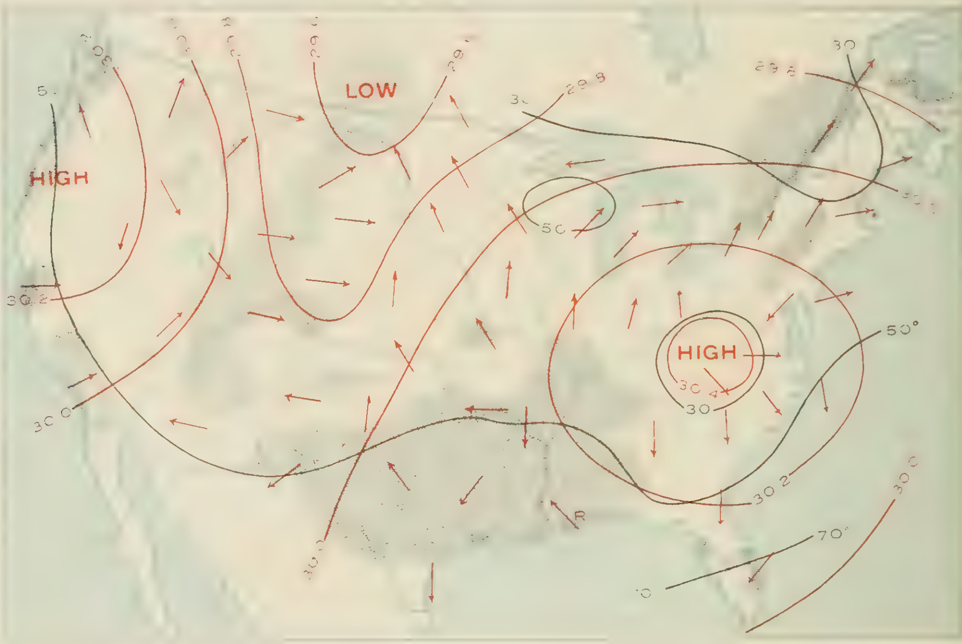

Fig. 169.—The Weather of October 29, 1903 (Indian Summer).

The earliest use of the term found by Mr. Matthews is in the following journal entry by Major Ebenezer Denny[2] while at Le Boeuf, a few miles from the present city of Erie, Pa., on October 13, 1794:

"Pleasant weather. The Indian Summer here. Frosty nights."

There is very little agreement among writers who used the term as to the time of occurrence of the Indian Summer, or as to the length of the

[1] Albert Matthews. The term Indian Summer. Monthly Weather Review for January and February, 1902 (Washington, D. C.).

[2] Military Journal, 1859, p. 198.

period. This is, however, not surprising in view of the fact that the type of pressure distribution which causes the characteristic weather may develop at any time of the year.

The meteorological conditions prevailing over the country on the morning of the 29th of October, 1903, at the beginning of a brief period of Indian Summer in the Middle Atlantic states are shown in the accompanying weather chart. An area of high barometric pressure, centered over the Upper Mississippi Valley on the 26th of October, moved slowly southeastward during the 26th, 27th, and 28th, and remained with slight changes of configuration and position over the Middle Atlantic and South Atlantic states until November 4, when it gave way to an area of low pressure over the Lake region, bringing general rains to the Atlantic coast states.

On the morning of October 29 the center of the high area was over Virginia. The skies were clear throughout the Middle Atlantic states, the winds were prevailingly from the southwest and light. (See Fig. 169.)

The following extracts from the records of the Baltimore Office of the United States Weather Bureau indicate the general character of the weather during the brief period of Indian Summer weather from October 28 to November 4, 1903:

October 28, 1903. Clear day. Warmer and pleasant; maximum 61°, minimum 40°. Light fog in morning. Wind was brisk at times during the day. Wind west and southwest. Average velocity 9 miles per hour; maximum velocity 22 miles from the west at 9.10 a. m.

October 29, 1903. Clear day. Somewhat warmer; maximum 68°, min imum 45°. Pleasant. Light fog at 8 a. m. Wind from southwest to northwest; average velocity 8 miles.

October 30, 1903. Clear day. Some cirrus clouds all day. Somewhat warmer; maximum 75°, minimum 52°. Pleasant. Light haze at 8 a. m. Wind from southwest to northwest; average velocity 5 miles.

October 31, 1903. Partly cloudy day. Sky a little more than half clouded all day. Somewhat cooler; maximum 68°, minimum 44°. Mild and delightful weather continues. Light fog in morning; light fog and smoke at 8 p. m. Wind variable, from southeast to northwest; average velocity 3 miles.

November 1, 1903. Clear day. Some cirrus present nearly all day. Somewhat warmer; maximum 74°, minimum 46°. The mild pleasant Indian Sum-

mer weather continues. Light fog in morning. Wind from west to northwest; average velocity 4 miles.

November 2, 1903. Partly cloudy day. Morning clear; mid-day partly cloudy, and sky overcast by late afternoon; evening clear. Warm in morning, cooler in afternoon; maximum 68°. Mild and pleasant. Light fog in morning and light smoke in evening. Winds variable; average velocity 4 miles.

November 3, 1903. Clear day. Warmer in afternoon; maximum 75°, minimum 48°. Continued mild and pleasant weather. Light fog in morning; light smoke at 8 p. m.; and light haze all evening. Wind west to northwest; average velocity 5 miles.

November 4, 1903. Partly cloudy day. Morning clear; sky became nearly overcast with light clouds just after noon, and so continued. Warm and pleasant weather continues; rather humid in afternoon. Light rain began 11.30 p. m. and continued at midnight; amount to midnight, 0.02 inch. Light fog in morning, light haze in evening. Lunar corona seen at 8 p. m., and a beautiful lunar halo of 22½° radius seen at 9.15 p. m. and at 10 p. m. Wind variable; average velocity 3 miles.

The Variability of Autumn Temperatures.

The extreme ranges of the temperature conditions during the fall months are shown in detail in the discussion of climatic conditions in Part I of this report; these statistical tables are supplemented by the records of weather conditions on two selected typical fall days, namely, October 1 and Thanksgiving Day, from 1871 to 1907, and on a State holiday, September 12, the anniversary of the battle of North Point. The variability of the weather of the fall does not differ materially from that of the spring—both seasons are transitional periods connecting the extreme conditions of winter and summer. A close study of these tables based on Baltimore observations for 37 years will give a fair idea of the variability of fall weather over the Coastal Plain of the Middle Atlantic states.

The Weather of September 12.

The 12th day of September, or Defenders' Day, is a state holiday in Maryland commemorating the battle of North Point in 1814. In the past 37 years the weather on this day has been mostly clear to partly cloudy, with an average temperature of about 72°, and extremes ranging between 93° and 51°. The winds have been light easterly, while rain has occurred on an average once in three years. The distribution of rainfall has been peculiar, having occurred 12 times during the first 20 years and but once in the succeeding 17 years.

THE WEATHER OF SEPTEMBER 12.

Year.	Max. Temp. (Degrees Fahr.)	Min. Temp.	Mean Temp.	Character of Day.	Wind Direction.	Daily Wind Movement. (Miles)	Precipitation (Inch)
1871	69	64	66	Cloudy	SE	70	0.01
1872	81	72	76	Cloudy	S	171	0.24
1873	78	58	68	Clear	N & SE	100	...
1874	90	70	80	Pt. cldy	SE	61	...
1875	70	52	61	Cloudy	E	143	...
1876	67	57	62	Cloudy	NE	140	0.01
1877	74	69	72	Cloudy	E	122	0.89
1878	80	69	74	Cloudy	E	174	...
1879	72	51	62	Clear	S	81	...
1880	77	56	66	Clear	SE	77	...
1881	81	69	75	Clear	N & NW	107	0.01
1882	72	61	66	Clear	N	183	0.03
1883	63	56	60	Cloudy	NE	281	1.13
1884	78	67	72	Pt. cldy	NE	117	...
1885	72	62	67	Pt. cldy	NE-SE-S	95	...
1886	86	61	74	Pt. cldy	NE-SW-W	129	0.53
1887	77	63	70	Cloudy	SW	118	0.64
1888	84	62	73	Clear	SW	158	0.01
1889	69	64	66	Cloudy	NE	368	0.55
1890	82	71	76	Cloudy	S	171	1.06
1891	76	60	68	Clear	NE & S	128	...
1892	79	61	70	Pt. cldy	SE	200	...
1893	70	60	65	Cloudy	E	239	...
1894	73	55	64	Clear	E	130	...
1895	93	73	83	Clear	W	126	...
1896	80	67	74	Cloudy	E & SW	62	...
1897	79	67	73	Cloudy	E	173	...
1898	74	53	64	Clear	N & NW	155	...
1899	82	57	70	Clear	SW & NW	105	...
1900	88	70	79	Clear	SW & NW	165	...
1901	87	69	78	Pt. cldy	SW	119	0.01
1902	75	57	66	Clear	S	153	...
1903	84	69	76	Clear	E	154	...
1904	87	62	74	Clear	N	123	...
1905	75	63	69	Cloudy	NW	138	...
1906	88	72	80	Pt. cldy	S & SW	151	...
Average	78	63	72			144	0.39

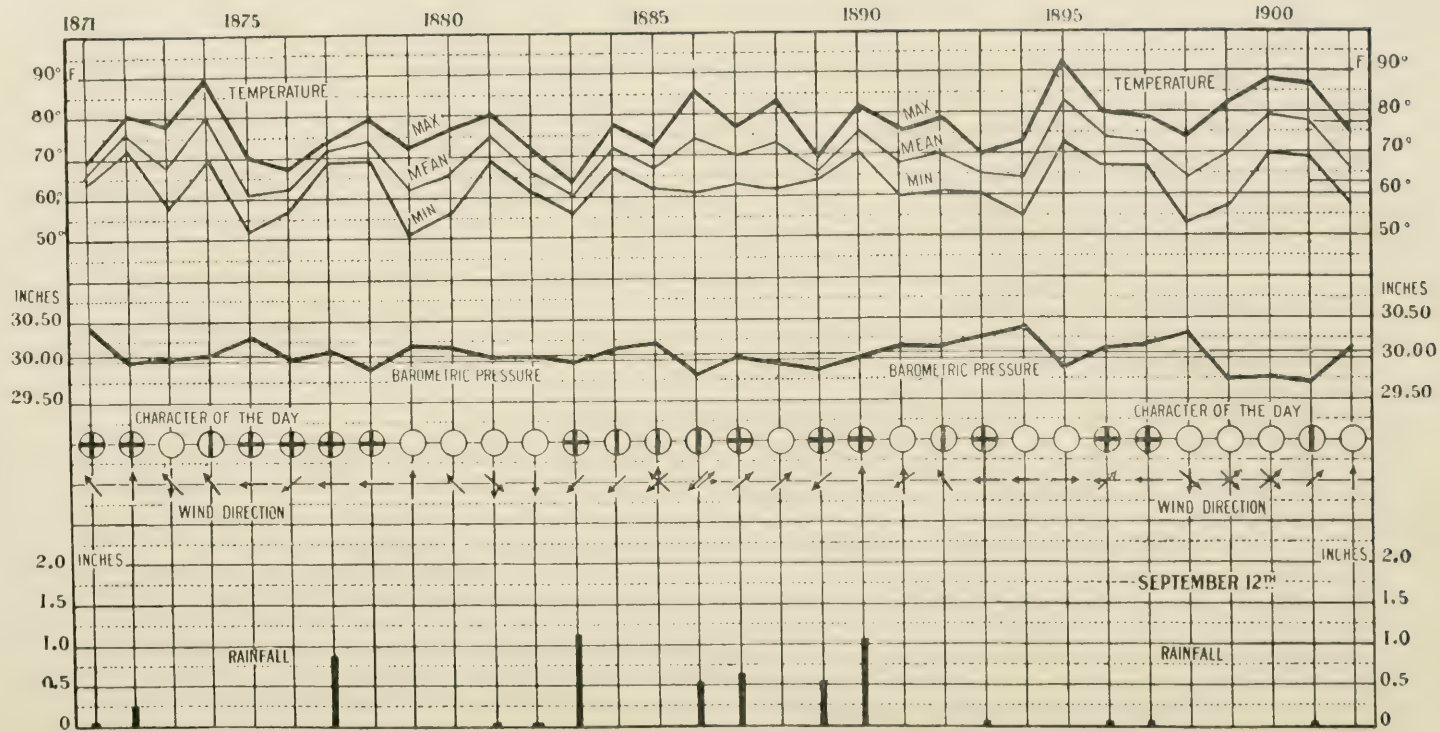

Fig. 170.—The Weather on September 12 (Defenders' Day).

The Weather of October 1.

The first day of October falls within a period likely to have some of the most delightful weather of the year. With an early morning temperature of about 54° and an afternoon temperature of 72°, the average for the day is 63°. The highest temperature for the day, occurring in 1889, was 89°, and the lowest was 39°, recorded in 1899. The record of cloudiness shows a high percentage of bright clear days: There were nineteen clear days, eleven partly cloudy days, and but five cloudy days in the entire period from 1871 to 1907. Rain occurred on but seven days of the 37 anniversaries, while the precipitation was evenly distributed through the period. The early part of October is the period of the year most free from rain. The winds have been light and mostly from a northerly direction.

The Weather of Thanksgiving Day.

Cloudy to partly cloudy weather, with moderate winds from the northwest, has prevailed on this day during the past 37 years in Baltimore. The mean temperature for the day has been about 40°, with an early morning temperature near the freezing point, rising to about 46° in the afternoon. The extremes for the day have ranged between 71° in 1896, to 21°, in 1903. Precipitation was evenly distributed through the period, and occurred on an average once in three years, generally in the form of rain. The amounts have been light, mostly less than a quarter of an inch.

THE WEATHER OF OCTOBER 1.

Year.	Max. Temp.	Min. Temp. (Degrees Fahr.)	Mean Temp.	Character of Day.	Wind Direction.	Daily Wind Movement. (Miles)	Precipitation. (Inch)
1871	69	50	60	Clear	NW	80	...
1872	66	53	60	Pt. cldy	NW	125	...
1873	66	47	56	Pt. cldy	SW	153	...
1874	64	48	56	Clear	SW	233	...
1875	72	52	62	Pt. cldy	NW	133	0.08
1876	60	45	52	Pt. cldy	W	100	0.40
1877	75	54	64	Pt. cldy	N	85	...
1878	73	54	64	Clear	NE & SE	89	...
1879	80	56	68	Clear	SE	61	...
1880	64	43	54	Clear	SE	112	...
1881	89	72	80	Clear	W	132	...
1882	75	60	68	Clear	N	61	...
1883	64	56	60	Pt. cldy	N & SE	148	...
1884	84	69	76	Pt. cldy	SE	67	...
1885	76	59	68	Cloudy	SE	104	0.31
1886	66	48	57	Clear	NW	187	...
1887	76	65	71	Pt. cldy	W	74	...
1888	71	46	59	Pt. cldy	SW	265	0.04
1889	78	61	70	Cloudy	SW	162	...
1890	70	51	60	Pt. cldy	NE	81	0.81
1891	69	51	60	Cloudy	NE & SE	200	..
1892	83	58	70	Clear	NE & S	213	...
1893	66	45	56	Clear	NW	184	...
1894	74	58	66	Clear	NW	137	...
1895	63	42	52	Clear	NW	178	...
1896	70	58	64	Pt. cldy	W	96	..
1897	88	58	73	Clear	NW	57	...
1898	78	58	68	Clear	NE & E	164	...
1899	56	39	48	Clear	NW	117	...
1900	70	65	68	Cloudy	NE	174	0.08
1901	71	55	63	Clear	SE & NW	80	...
1902	77	64	70	Pt. cldy	NW	192	1.11
1903	79	53	66	Cloudy	SW	133	...
1904	73	54	64	Clear	W	287	...
1905	87	59	73	Clear	W	68	...
1906	57	52	54	Cloudy	NE	246	...
Average	72	54	63			138	0.40

THE WEATHER OF THANKSGIVING DAY.

Year.	Date Nov.	Max. Temp.	Min. Temp.	Mean Temp.	Character of Day.	Wind Direction.	Daily Wind Movement.	Precipitation.
		(Degrees Fahr.)					(Miles)	(Inch)
1871	30	35	29	32	Cloudy	NW	255	...
1872	28	41	29	35	Pt. cldy	SE	106	...
1873	27	52	34	43	Pt. cldy	SW	141	...
1874	26	41	28	34	Clear	N	...	...
1875	25	41	30	36	Clear	SE	134	...
1876	30	39	25	32	Cloudy	N	97	...
1877	29	51	33	42	Pt. cldy	NW	149	0.01
1878	28	52	44	48	Cloudy	NW	249	0.01
1879	27	51	33	42	Pt. cldy	SE	71	...
1880	25	36	30	33	Cloudy	N	83	0.18
1881	24	41	28	34	Pt. cldy	NW	272	0.14
1882	30	36	28	32	Clear	NW	208	...
1883	29	43	34	38	Clear	S	106	...
1884	27	54	31	42	Cloudy	SW	111	...
1885	26	44	35	40	Cloudy	NW	223	...
1886	25	50	34	42	Cloudy	NW	224	1.07
1887	24	48	45	46	Cloudy	NE-E-NW	77	0.01
1888	29	46	37	42	Cloudy	W	177	...
1889	28	56	43	50	Pt. cldy	SW & NW	153	0.69
1890	27	37	32	34	Cloudy	N & NW	133	...
1891	26	44	38	41	Cloudy	NE & E	126	0.08
1892	24	36	21	28	Clear	W	392	...
1893	30	54	46	50	Clear	SW & W	148	...
1894	29	35	24	30	Clear	N	130	...
1895	28	48	31	40	Clear	N	80	...
1896	26	71	49	60	Pt. cldy	SE	73	...
1897	25	46	32	39	Pt. cldy	SE	70	...
1898	24	35	30	32	Cloudy	N	177	0.20
1899	30	62	41	52	Pt. cldy	SE	60	...
1900	29	52	40	46	Cloudy	SE	70	...
1901	28	33	25	29	Clear	W	135	...
1902	27	49	39	44	Pt. cldy	NW	236	0.11
1903	26	33	21	27	Pt. cldy	NE	114	...
1904	24	54	37	46	Pt. cldy	NW	226	...
1905	30	49	25	37	Pt. cldy	NW	336	...
1906	29	45	33	39	Clear	NW	223	...
1907	28	57	43	50	Cloudy	SW	173	...
Average		46	33	40			159	0.25

THE HEAVY RAINS OF SEPTEMBER 24-26, 1902.

The closing week of September was marked by heavy and long continued rains throughout the Middle Atlantic and New England states. The period preceding had been one of deficient precipitation in Maryland, but the rains of the 24th, 25th, and 26th, and the heavy shower of the 30th, gave the month a total fall far in excess of the normal September amount.

From the 16th to the 22d the winds were mostly from the northeast and east. On the afternoon of the 23d there was a change to southeast and southwest, which direction prevailed to noon of the 24th, when it again returned to northeast. Rain set in about nine o'clock at night of the 24th and increased rapidly in intensity. By midnight about one inch had fallen. During the remainder of the night only a trace fell, the wind continuing from the northeast. From 8 a. m. of the 24th until 5 p. m. of the 26th the rainfall continued with scarcely any interruption. A change in the wind from northeast to southeast at 8 p. m. of the 24th was accompanied by a sudden increase in intensity, and heavy showers continued to fall throughout the night. Late in the afternoon of the 26th the rain ceased, with a change in the direction of the wind to northeast.

The total amount of rainfall for the three days as measured at the station of the United States Weather Bureau was 5.29 inches. About one inch of this amount fell during the showers of the 24th, lasting about three hours; the remainder fell during a continuous rain of nearly 36 hours. The rate of fall was never excessively heavy, but the storm was remarkable for the long uninterrupted fall of rain.

During the entire period the winds were light, exceeding 10 miles an hour for only a few hours, with a maximum velocity of 16 miles, and an average velocity of about 6 miles. The barometer was remarkably steady. There was no decided fall, but only a slow rise from midnight of the 23d to midnight of the 24th, and then a slow but steady fall to the 27th. The heavy shower of the 24th fell with a rising barometer.

The daily weather charts of the 24th to the 27th show an unusually sluggish movement of the areas of high and low pressure. An anti-

cyclone prevailed over the Lake region on the 24th, and then moved slowly eastward and remained nearly stationary over the New England states for two or three days. In the Mississippi Valley the pressure was comparatively low, with a long trough-shaped depression which did not develop into a well defined storm center until after the occurrence of the heavy rains at Baltimore.

FORETELLING THE WEATHER. (*Historical.*)

INTRODUCTION.

If we are to believe the statements of certain Greek philosophers and historians, the art of foretelling the weather is a lost art. In Aristotle's Politics we find this anecdote related about Thales of Miletus, the wisest of the seven sages of Greece: Thales was apparently accused by his neighbors of lacking the ability or the energy to make money. Desiring to convince them that his poverty was due to choice and not to necessity, and perceiving by his skill in astrology, during the winter, that there would be a great crop of olives that year, he contrived to hire at small cost all the oil presses in Miletus and Chios, as there was no one to bid against him. When the season came for making oil and the demand for presses was great, he disposed of them at his own figures, as the entire supply was in his possession. Thus he convinced his slanderers that it was easy for philosophers to be rich if they desired to be, but that this was not their aim in life.

During the twenty-five hundred years since Thales is credited with having cornered olive presses as a result of a seasonal forecast of the weather, there have been many successful corners of the markets, but the operators have passed from Academic groves to the Stock Exchange. The long range prophet of to-day has lost caste with his contemporaries and apparently lacks the ability to enrich himself by plying his vocation. After centuries of effort to foresee changes in the weather about us we must still be content with an imperfect glimpse one, two, or at most, three to four days into the future.

The methods employed in earliest historic times in foretelling the weather are in vogue to-day, though the accumulated experience of centuries of close observation of weather sequences has made some of them more accurate, while the result of modern research and the use of the electric telegraph have added a new method which is now firmly established in the official organizations of all civilized nations. There was probably a time in the development of all races when the weather was believed to be under the arbitrary rule of weather deities or of evil spirits. With the progress of civilization and a closer observation of the elements the belief in fixed laws or sequences in weather conditions became firmly established in the minds of the philosophers of the time, and the search for causes was begun.

NATURAL SIGNS.

As early as the time of Homer (about 950 B. C.) the four principal winds were named and their characteristics noted for the vicinity of Greece: *Boreas* was the cold stormy north wind; *Euros* the clear and bright easterly wind; *Notos* the moist south wind; and *Zephyros* the glorious west wind which brings on the spring. A manuscript of the time of Nero (37-68 A. D.) is said to contain a record of the probable weather for nearly every day in the year, especially as to wind direction, which would indicate that at that time regular observations of the weather must have been made in Rome.[1] Prognostics based upon a close observation of the weather and shrewd inference as to sequences, form a valuable part of the literature of weather probabilities: they are built upon a firm basis, but require discrimination in their application. If traced to the region of their origin many would doubtless be found to apply with considerable accuracy to actual conditions in the locality for which they were formulated. Removed from their original horizon and applied to remote regions they may fail to have any significance. It is not to be expected that the proverbs of the Greeks and Romans as collected by Aristotle, Theophratus, Aratus, and Pliny, and

[1] Hellman, G. Die Anfänge der meteorologischen Beobachtungen, 8. Berlin, 1893.

which may aptly fit the climatic conditions of Southern Europe should prove of the same value when transplanted to the totally different climates of Northern Europe, Great Britain and North America. Yet a large number of the proverbs current to-day in this country can be traced back through the English and German folk literature to early Greek and Roman weather proverbs. These proverbs have been modified and added to from time to time as observation or fancy have dictated. Many of them have a common application in widely scattered portions of the globe and find their interpretation in a study of the modern synoptic weather charts.

"The moon in a circle indicates a storm."

"When bees to a distance wing their flight,
Days are warm and skies are bright;
But when their flight ends near their home,
Stormy weather is sure to come."

"Do business with men when the wind is from the northwest."

In the temperate regions of the earth there is an eastward drift of storms and general weather conditions. The advance of a storm area is marked by increasing humidity, by characteristic cloud formations, systematic changes in the direction of the wind, by certain optical phenomena like lunar and solar halos, and brilliant cloud tints. The increased humidity produces a greater sensitiveness to changes in temperature, causes irritability and oppressiveness. These facts were recognized as signs of an approaching storm long before the general nature and movements of storms were known.

"If the rain falls during an east wind it will continue a full day."
"If it rains before seven it will stop before eleven."

The average rain lasts less than four hours, while a rain storm beginning with an east or northeast wind is likely to continue all day.

"A year of snow, a year of plenty."
"Much snow, much hay."
"A snow year, a rich year."
"Snow is the poor man's fertilizer, and good crops will follow a winter of heavy snowfall."

The protective value of a good covering of snow has long been recognized by the farming community. It supplies moisture, and prevents alternate freezing and thawing of the ground, so injurious to winter wheat.

> " A late spring is a great blessing."
> " When gnats dance in February, the husbandman becomes a beggar."
> " It is better to see a troop of wolves than a fine February."

These and similar proverbs are expressions of the harmful consequences of an early spring.

ASTRO-METEOROLOGY.

There is another class of weather forecasts much less worthy of respect, but supported by a deeply rooted and widely prevailing faith in the influence of the planets upon the weather. This popular belief in the planetary influence, especially as it relates to the moon, though combated for centuries will not be downed, and it is probably as firmly fixed in the minds of men to-day as it was in the middle ages, and earlier, and still controls the acts of many a man from the planting of corn to the cutting of his hair.

> " The peach crop never fails when the first blossoms appear in the light of an increasing moon."
> " If the new moon appears with the points of the crescent turned up the month will be dry; if the points are turned down it will be wet."

Belief in the influence of the moon is not unreasonable. The sun is too methodical in his movements to account for the abrupt and varied changes of weather in our latitude. The great variety of phase and varying combinations of position shown by the moon and planets suggested a ready explanation for any possible change of weather, and we find at a very early period a particular influence ascribed to each planet and to each phase of the moon.

> " The moon and the weather
> May change together,
> But change of the moon
> Does not change the weather.

If we'd no moon at all,
And that may seem strange,
We still should have weather
That's subject to change."
—*Notes and Queries, 1875.*

According to a well known authority[1] on the early literature of meteorology, the Greeks at first employed only the natural weather signs, such as winds, clouds, optical phenomena, etc. Later there was added a kind of calendar founded upon actual observations and giving average values. These were posted in public places, and had originally more of climatological matter than of prophecy. To fix the dates astronomical phenomena were employed, such as the rising and setting of stars. This association of weather elements with the stars and planets, intended simply to indicate time, came to have a causal connection attributed to it. The error was combated by some of the Greek philosophers, especially by Gemenius[1] (about 70 B. C.), to whom is attributed the following passage:

"Concerning the teachings of weather phenomena, there is a prevalent and erroneous superstition that atmospheric phenomena depend upon the rising and setting of the stars. Mathematics and natural history teach a totally different conception."

These warnings were unheeded, however, and under the influence of the Alexandrian school astro-meteorology constantly won in favor. The most renowned astronomer of ancient times, Ptolemy (about 140 A. D.), was also the greatest astrologer and laid the foundation of weather prophecy on astrological principles. His teachings were supreme for many centuries.

The Arabians were also ardent followers of astrology and they spread their views through Moorish Spain into Christian lands. Here astrology obtained a firm footing among the common people, under the protection of princes and the church. Toward the end of the XII century there arose a custom of foretelling not only weather phenomena, but also political and religious events for a year in advance.

[1] Hellman, G. Wetterprognose und Wetterberichte, 8. Berlin, 1893.

SYMBOLIC DAYS.

There is another class of weather proverbs based upon time-honored superstitions but not so persistently belived in as those based upon the moon's influence. The belief that the weather of the first twelve days of the new year in some way symbolized the general character of the entire year is very old. Traces of it are found in the customs of many nations. In Christian lands these symbolic days have been transferred to the twelve days beginning with Christmas and ending with Epiphany, while many more such days have been added to the calendar. As examples of this class may be mentioned Candlemas (February 2), the familiar ground-hog day, and July 15, St. Swithin's day.

"If on Candelmas day it is bright and clear the ground-hog will stay in his den, indicating that more cold and rain are to come; but if it snows or rains, he will creep out as the winter is ended."

"If Candlemas be fair and clear
Ther'll be two winters in the year."

"In this month is St. Swithin's Day,
On which if it should rain they say,
Full forty days after it will
Or more or less some rain distil."

"Three days of September (20, 21, 22) rule the weather for October, November, and December."

Of the same fanciful character are the sayings which belong to the class with the following:

"When squirrels lay in a large supply of nuts, expect a cold winter."
"A double husk of corn indicates a severe winter."

EARLY BOOKS ON WEATHER PROVERBS.

There are two very old booklets relating to weather proverbs which exerted a wide influence in the 16th and 17th centuries, especially in Germany, though literal translations soon found their way into all European nations. One of these bearing the title "Reynman's Weather Book" first appeared in print in 1510 and was the earliest meteorological work printed in the German language. It is a little book of about 12

pages dealing mostly with natural weather signs as is shown by the following table of contents:

Contents of Reynman's "Wetter Büchlein."

(1) Circles about the sun and moon.
(2) Colors of the stars and of shooting stars.
(3) Weather signs at sunrise and sunset.
(4) The clouds.
(5) The rainbow.
(6) Signs of the seasons.
(7) The new and full moon.
(8) The winds.
(9) Hail.

About the same time (1508) there appeared a somewhat similar weather book of the true folk-literature type, entitled "Bauren Praktik," of which Dr. Hellmann has noted about 60 editions belonging to the 16th, 17th, 18th, and 19th centuries, in Germany alone, in addition to a host of translations which appeared in other countries. The greater portion of this little book is devoted to forecasts of the weather for the entire year as indicated by the weather of Christmas Day and succeeding days to the 5th of January.

Translations of these books gained a wide circulation in England during the 16th and 17th centuries under the titles "The husbandman's practice, or prognostication forever," and "The Book of Knowledge."

An extract from the preface of one of the early English editions of the "Bauren Praktik" is here given:

"The wise and cunning masters in Astronomy have found, that man may see and mark the weather of the holy Christmas night, how the whole year after shall be on his working and doing, and they shall speak on this wise.

"When on Christmas night and evening it is very fair and clear weather, and is without wind and without rain, then it is a token that this year will be plenty of wine and fruit: But if the contrariwise, foul weather and windy, so shall it be very scant of wine and fruit. . . ."

FORECASTS BASED ON AVERAGE AND EXTREME VALUES.

The method of average and extreme values of weather conditions of a given place as a basis of weather forecasts has an extremely limited application in our latitudes. There are regions where the weather con-

ditions of any given day of the year do not vary greatly from the average conditions for the month, where one day is very much like another for months at a time, and where a long-range forecast can safely be made. Such conditions are, however, not found north of latitude 20° or 25° in the belt containing the great bulk of the civilized nations of the earth. Here changes in the weather are so rapid and so irregular that the figure representing the average temperature for the month affords very little clue as to the temperature of any given day in the month. The average temperature for the month of February, for example, at Baltimore is 35°; on the 23d of February, 1874, the temperature rose to a maximum of 78°, on the same day of the month in the year 1873 a minimum of 12° was recorded, and on the 10th of February, 1899, during the great blizzard it fell to 7° below zero, an absolute range of 85°.

Temperature Variability.

The diagrams presented on Plate III and Plate IV show very clearly the great changes to which we are subjected in Baltimore during the course of the year. On Plate III is shown the average value of the highest and lowest temperature for each day for 30 years, and the mean between the average maximum and average minimum, that is, the daily normal temperature based on 30 years' observations. These diagrams indicate the most probable readings of the thermometer to be expected upon any given day of the year; but such values may prove to be a delusion as a basis for prediction. On plate IV we have the absolute extremes of temperature occurring upon each day of the year during the past 30 years; also a line representing the difference between the extremes, or, as it is called, the "extreme range" for each day in degrees Fahrenheit. This curve presents some interesting characteristics of Baltimore weather. The most noticeable feature is the great variability during the winter months as compared with the summer months. The greatest fluctuations occur in February, although those of March and April are not far behind.

Rainfall Probability.

There is no meteorological element so irregular in its method of occurrence, or in quantity, as rainfall. Hence it is extremely hazardous to

discuss rainfall probability. The history of the 30 years from 1871 to 1902 presents many instructive features, and we may even venture to draw some inferences of a general character as to the future. On Plate IX will be found several diagrams relating to the probable occurrence of rain or snow at Baltimore for each day of the year, expressed in percentage of the possible number. For example, on the 5th day of July it rained 15 times in the past 30 years, or 50 per cent of the possible number of days. This may be considered as a percentage of rainfall probability, although the figure has little value. The value as a prophecy is increased, however, if we reduce the figures to 5 or 10 day means.

SPECIAL DAYS.

The variability of weather conditions upon any given day may also be shown in another way. In the chapter on winter the weather of each 22d day of February for a long series of years at Baltimore is represented. The highest and lowest temperatures of the day, the height of the barometer, the amount of cloudiness, the prevailing wind direction, and the rainfall or snowfall, are shown.

The average conditions on the 22d of February would be represented by a maximum temperature of 46°, an average temperature of 36°, and a minimum of 32°, with a westerly wind, partly cloudy weather, and with little or no precipitation. During the past 37 years there were 16 clear days, 12 partly cloudy days, and 9 cloudy days. Rain or snow fell during some portion of the day or night on 13 days, but only on 5 days after 9 a. m.

Based upon such facts the following calculation was made as a matter of curiosity early in February of 1902 to ascertain the chances in favor of a fair day on the 25th anniversary of the opening of the Johns Hopkins University:

There were 2 chances in 3 in favor of a clear or partly cloudy day.

There were 3 chances in 4 in favor of a day without rain or snow.

There were 8 chances in 9 in favor of a day without rain or snow after 9 a. m.

The day proved to be one of the most disagreeable in local chronology. (See page 373.)

RECURRING PERIODS.

The search for periodic recurrences of similar weather conditions has long been a favorable pursuit of those engaged in the study of the weather. The problem has been approached from two directions. First in the order of time was the effort to associate all weather changes with the planets, the stars, the comets, and shooting stars. After the invention of the thermometer, the barometer, the rain-gauge and other instruments which permitted the recording of accurate observations, the statistical method made its appearance, by means of which recurring periods in the weather may be detected in a long series of observations. Both methods are still employed. The position of the sun as the controlling factor was of course apparent and at once acknowledged. On the other hand the influence of the moon, the planets and the stars was a pure assumption. The ingenuity and energy displayed in the past century to fit the facts of observations into the periods of rotation, the conjunctions, the oppositions, and the phases of these heavenly bodies, are worthy of the highest praise, though the judgment displayed has not always been so commendable. The search is still vigorously carried on, but it has been narrowed down to the influence of the sun and moon. Faith in the moon's influence is by no means confined to any particular class of men; her defendants are among the wise and unwise. The direct effect of the moon in causing atmospheric tides is now generally admitted to be too small to cause an appreciable effect upon weather conditions. There is some probability of proving that the motion of the moon in declination may cause a slight shift in the positions of the persistent areas of high and low atmospheric pressure, and in this way divert the paths of storms to a small extent. This theory has at least the advantage of reconciling some of the contradictory results obtained in tabulating observations of weather conditions, and allows one investigator to find an increase in the number of storms at the same time that another finds a decrease in some other not very distant locality.

The particular phase of the question of periods in weather conditions receiving most attention at the present time is the relation existing between sun-spots and prominences and the weather. Every imaginable

terrestrial phenomena is being charted in connection with the eleven year curve of sun-spot frequency: Magnetic disturbances, temperature, pressure, auroras, rainfall, storm frequency, droughts and famines, earthquakes and volcanic eruptions, the price of wheat, etc. A close relationship has undoubtedly been established between the sun-spot frequency and magnetic and electrical disturbances at the earth's surface. When we come to a similar comparison of weather elements the conformity is not so clear.

The annual changes in temperature, pressure, rainfall, and storm frequency at Baltimore from 1817 to 1902 and the sun-spot frequency during the same period are represented in Plate XII. It is difficult to find any suggestion of synchronous changes in these curves.

Examining the question of periodicity from the statistical point of view there is very little encouragement for those who hope to build up a system of prophecy upon regularly recurring periods in our latitudes. A long series of accurate observations is the first essential, especially when the period sought for extends over a number of years. One difficulty is that the amplitude of pertubation is great compared with the periodic variation, making the latter difficult of detection. Another difficulty has been an undue eagerness to regard coincidence as evidence of a true periodicity.

In Europe there are several series of temperature and rainfall abservations covering from 100 to 200 years. The rise and fall of lake levels, the advance and retreat of glaciers, the character and time of vintage, the opening and closing of rivers to navigation; these facts have been carefully noted for many years. A careful study of such data has led one European, Prof. Brückner, of Berne, to the opinion that there is a recurring period of 35 years of warm and dry and cold and wet seasons. Other investigators have thought that they detected periods of 17 years, of 19 years, and of 55 years. The amounts of variation in all cases have been small and the periods ill defined. In short it may be said of all of the supposed periodicities thus far detected that the best of them are regular enough to warrant further investigation, and uncertain enough to be worthless as a basis for weather prophecy.

One of the most eminent climatologists of Europe, Dr. Hann, of Vienna, is authority for the following statement in a recent publication:[1] "It has not been possible to establish a marked cyclical variation of any one of the meteorological elements." He also states:[2] "There is no evidence of decrease or increase in the observations of mean temperature in the past 200 years in Europe; and all indirect testimony likewise goes to show that there has been no progressive change in temperature anywhere in historic times." There are, of course, warm periods followed by cold periods and wet periods followed by dry, extending over a series of years, but the amplitudes vary greatly and also the periods. This is readily seen in the Baltimore temperatures shown in the curves on Plate XII.

Concerning shorter periods of a few days or a few months we have the same conflicting testimony:

"Is a mild January followed by a cold May." "Is a warm March followed by a warm spring." "Is the cold of winter proportional to the amount of rainfall in autumn," as the Indians are supposed to have taught the early inhabitants of Pennsylvania.[3] "Is a wet September followed by a favorable wheat crop." These and many more similar sayings are current among the weather wise. If there were any such simple sequences it is safe to say that they would long since have been discovered. (Consult Plates VI and VII, temperature departures, 1817-1902; and Fig. 54, and Plate X, rainfall departures.)

THE METHOD OF THE SYNOPTIC WEATHER CHART.

A new principle in weather forecasting was announced when Benjamin Franklin, in a letter to a friend, dated July 16, 1747, stated that "we have frequently, along the North American coast, storms from the northeast which blow violently sometimes three or four days. Of these I have had a very singular opinion some years, viz., that though the

[1] Hann, J. Lehrbuch der Meteorologie, 1901, page 626.

[2] *Ibid.*, page 110.

[3] Matthews. The Term Indian Summer. U. S. Mon. Weather Review, Jan. and Feb., 1902.

course of the wind is from the northeast to southwest, yet the course of the storm is from the southwest to the northeast, that is, the air is in violent motion in Virginia before it moves in Connecticut, and in Connecticut before it moves at Cape Sable." Franklin arrived at this conclusion at the time of the eclipse of the moon of October 21, 1743. He had made preparations for observing the eclipse at Philadelphia, but clouds accompanying a northeast storm obscured the moon during the night. A few days later he learned in letters from Boston that the night was clear at the time of the eclipse, but that clouds soon after appeared and that a northeast storm occurred on the following day. Later correspondence with friends in the southern states developed the fact that the northeast storm was experienced successively in Georgia, Virginia, Pennsylvania, and Massachusetts. These conclusions were confirmed by later observations and led Franklin to the generalization that storms move from southwest to northeast in our country.

The discovery was, however, too far ahead of the times to result in any practical benefits, as the utilization of the knowledge required means of rapid communication which were not then in existence. The same principle was announced as a new idea about fifty years later in Europe. Not until after the practical introduction of the telegraph could the idea be made fruitful.

The history of the establishment of the first national storm warning system is interesting and instructive. In 1854 the principle of the eastward movement of storms, and hence the possibility of foretelling their appearance, was common knowledge among scientific men, when an incident occurred which drew the attention of the whole world to the practical importance of establishing a system of storm warnings. The Crimean war was in progress. On the 24th of November, about 20 days after the famous "Charge of the Light Brigade," a terrific storm swept over the Black Sea. High winds, heavy rain, sleet and snow during the night were followed the next day by intense cold. The allied fleets of the British and French forces were almost wiped out of existence. The loss of life and destruction to property were appalling. Investigation disclosed the path of the storm which had brought such havoc. The day

preceding it had passed over Southern Austria, the day before that it was experienced in France. It was now a comparatively easy matter to convince legislative bodies of the great practical value of storm warnings. LeVerrier in France was the first to take advantage of the favorable opportunity and in less than two years the French system of daily telegraphic reports and weather forecasts was established. Other nations soon followed the example of France, and to-day there is scarcely a nation of prominence without its system of storm warnings.

The first practical application of the new principle of weather forecasting based upon telegraphic reports in this country was made by the Smithsonian Institution in 1856. Upon the suggestion of the Secretary, Prof. Joseph Henry, the Superintendent of the Western Union Telegraph Company instructed his operators all over the country to replace the words "good night" at the close of the day's work by dispatches indicating the character of the weather at the time. This information was exhibited, by means of colored symbols, upon a blackboard map of the United States on the following day. Professor Henry soon observed that the kind of weather experienced in the Ohio Valley generally reached the Middle Atlantic Coast states on the following day.

Our own national service was established by Act of Congress in February, 1870, largely owing to the pioneer efforts of the Smithsonian Institution, Prof. Abbe, of the United States Weather Bureau, at that time Director of the Cincinatti Observatory, and of Representative Halbert E. Paine.

A long step in advance was made in the practical work of weather forecasting when the idea of simultaneous observations was introduced. Observations were first made at stated hours, local time; in such a system the observations on the Pacific Coast would be made more than three hours after those made in the Atlantic Coast states, though at the same hour of local time. It was necessary to set a common hour for all observations, so as to give us a picture of the actual weather conditions at a given moment of time. In this country and in Canada the hours in use are 8 a. m. and 8 p. m., Eastern or 75th meridian time, the time used in all of the Atlantic Coast states.

The method of collecting the telegraphic observations made by the United States Weather Bureau, and charting them for purposes of weather forecasting, is fully described in Vol. I of the Maryland State Weather Service Reports, in the paper by F. J. Walz, a forecast official of the Bureau. The principles involved in forecasting are also treated at some length in the same volume; and the reader is referred to this report for additional information.

THE INDIAN SEASONAL FORECASTS.

At the present time there is not one among all the national weather services in the temperate regions that is attempting weather forecasts for a longer period than three or four days. The variability of weather conditions is so great that any period of a longer duration which may exist is completely masked by the large daily fluctuations. In the lower latitudes the changes from day to day are smaller, and a departure from normal conditions is more significant, while there is greater regularity in seasonal changes. It was, therefore, to be expected that long range forecasts would find their first application in the tropical and sub-tropical regions of the world. The Indian Meteorological Service was the first to make a serious attempt to issue forecasts for months in advance. Such forecasts have been made since 1888 and have at least been successful enough to encourage the hope that they will eventually prove to be of vast benefit to the teeming millions in the agricultural regions of India.

In India the probability of a light or a heavy rainfall during the summer months is always a question of vital importance. With its 200,000,000 of population, and with very limited means of rapid transportation a partial drought means starvation to thousands, while pronounced droughts over comparatively limited areas have brought death to millions of inhabitants.

During the famine of 1837 the loss of life by starvation was estimated to be about 800,000; in the famine of 1832-3, 150,000; 1860-1, 500,000; 1865-6, 1,000,000; 1868-9, 1,500,000. During the later droughts, namely, 1873-4, 1876-7, 1877-8, 1899-1900, the loss of life was com-

paratively small, owing to increasing facilities in transportation, permitting rapid distribution of relief supplies.

The summer monsoon rains of July, August, and September are relied upon almost entirely for the season's crops, the winter rains being light and comparatively unimportant. So the one great problem is to find early in the season some signs of the probable character of the monsoon winds which bring the rains from the Indian Ocean. Close investigation of conditions during the past 30 years by the officials in charge of the excellent meteorological service established there by the British Government, has resulted in the formulation of a few rules which have been applied with encouraging success in anticipating the probable amount of rainfall of the summer in June.

Early in June a forecast is issued by the Director of the Indian Meteorological Service as to the probable character of the approaching southwest monsoon rains, based on the amount of snowfall during the past winter months in the mountain regions to the north of India, and on the marked departures from normal conditions all over India and the adjacent seas during the preceding five months.

The conditions which chiefly influence the extension and strength of the southwest monsoon winds are:[1]

1. The amount and time of occurrence of the cold weather snowfall in the mountains.
2. The local peculiarities of the weather in India immediately before the abrupt advance of the monsoon currents across the coasts of Bombay and Bengal into the interior. These abnormal features are best estimated by means of the variations of pressure from the normal.
3. Local peculiarities over the Bay of Bengal and the Arabian Sea, over which the monsoon currents pass before they reach India, and probably also the Indian Ocean which is the source of the southwest monsoon current.

Heavy and prolonged snowfall in the mountain areas tend to prevent or delay the extension of the monsoon current over Upper India. Heavy and untimely snowfall in April and May especially exercise a powerful influence in this way.

[1] *See:* Memoire on the snowfall in India. 1900. 4°. Calcutta, 1901.

Apparently any large and persistent variation in the strength of the southeast trades would affect the strength of the southwest monsoon. This was probably the chief factor in the failure of the monsoon rains of the summer of 1899 in India.

Before the advance of the southwest monsoon occurs, light unsteady winds prevail in May in the Arabian Sea. The advance commences in the neighborhood of the equator and is due to actions chiefly over the Indian Ocean, the result of which is that the current of the southeast trades is impelled across the equator and thence northeastward over the Indian seas, and the heated regions in South Arabia, India, and the Malay Peninsula. The advance of the current is accompanied by heavy squalls, with much rain, and when fully accomplished gives strong steady humid winds for some months in the Indian seas. These humid winds are directed to the regions named above and give frequent heavy rains, the distribution and amount of which depends upon a variety of causes.

The cause of the failure of the rains and drought of the monsoon of 1899 was apparently the abnormal deviation of the southeast trade winds to South Africa, and their subsequent weakness in the Indian Ocean. The result of this was that, after a short burst of humid winds in June, the monsoon practically collapsed in the Arabian Sea, and the air movement in July, August, and September resembled that of May in character, and brought up comparatively little aqueous vapor from the Indian Ocean. Hence little or no rain occurred during the greater portion of the monsoon period in the areas which receive their monsoon rainfall from winds which advance across the Arabian Sea, and the consequent drought and famine was the most serious which has visited India in the past 100 or 200 years.

It is very doubtful at present whether this method of basing seasonal forecasts on the monsoon effects will ever be applied to conditions in the temperate regions of the globe. The cyclonic changes are so much greater than the monsoon effects between continent and ocean that the latter periodic movements are completely masked.

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